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EFFECT OF SOME CHEMICALS ON THE GERMINATION OF UREDOSPORES OF *PUCCINIA PENNISETI* ZIMM.

By

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Read at the 28th Annual Session of the Academy held at the University of Agra on 8th February 1959.

INTRODUCTION

The influencing role of certain organic compounds in retarding or completely inhibiting spore germination and subsequent development of diseases has attracted the attention of plant pathologists since long and quite an extensive literature has accumulated on this subject (Gassner & Hassebrauk 1936, Hassebrauk 1938, Hart & Allison 1939, Van Der Vliet 1953 etc.). It has been shown, in recent years, that in addition to organic compounds, certain antibiotics (Gambogi 1952), sulpha-drugs (Hassebrauk 1951, Hotson 1952 and 1953), synthetic phytohormones (Ibraham 1951, Peturson 1951, Witsch & Kasperlik 1953) and fungicides (Hashioka & Morihashi 1952, Scaramuzzi 1954, Zobrist & Hoffmann 1953, Van Der Vliet 1955, Ellis 1954a and 1954b); inhibit, sometimes, with success, the growth of certain rust fungi. The chemical compound is generally applied either as a spray (spraying the foliar parts) or added to the soil.

The present paper deals with the influence of certain sulpha-drugs, antibiotics, fungicides and synthetic phytohormones on percentage inhibition of uredospore germination of *Puccinia penniseti* Zimm., causing rust disease of *bajra* (*Pennisetum typhoides* Stapf & Hubb.).

METHOD AND MATERIALS

Germination tests of uredospores of *Puccinia penniseti* Zimm. were performed in hanging drop cultures at 14 - 15°C optimum for germination. The required temperature was maintained in a refrigerator cabinet suitably adjusted for the purpose. Counts were made for the percentage spores remaining ungerminated (i. e. percentage inhibition) in 24 hours.

10, 100, and 1000 ppm concentration of sulphadiazine, sulphathiazole, sulphaguanidine, penicillin, streptomycin, blitox-50, coppesan, dithane z-78, fytolan, perenox, wettle sulphur, 2, 4-D, NAA and IAA were used. Pyrex-glass-distilled water was used to serve as control and separate control was maintained for each chemical. The chemical solutions of the test material were also prepared in pyrex-glass-distilled water. Fresh uredospores were used for each treatment so as to eliminate age variations. The data was subjected to statistical analysis, following the 'analysis of variance' method on factorial basis, and only the significant differences have been considered for interpreting the results, included in Table I.

RESULTS

TABLE I

Effect of the various chemicals on percentage inhibition of uredospore germination in *Puccinia penniseti* Zimm.

(Mean of 50 values)

Chemical		Concentration in ppm				Average	C. D.
		0	10	100	1000		
Sulphadiazine	...	8·71	40·89	52·84	58·84	40·33	
Sulphathiazole	...	9·23	36·31	43·30	63·92	38·19	
Sulphaguanidine	...	9·21	34·47	45·93	68·27	39·41	
Penicillin	...	6·23	11·46	17·44	32·09	16·80	
Streptomycin	...	6·50	20·09	28·18	58·14	28·23	
Blitox-50	...	7·55	12·19	18·18	26·77	16·17	
Coppesan	...	6·18	12·70	35·52	83·23	34·41	
Dithane Z-78	...	6·19	19·14	100·00	100·00	56·33	2·05
Fytolan	...	8·14	13·22	36·15	79·17	34·17	
Perenox	...	8·04	12·03	27·82	81·96	32·46	
Wettle Sulphur	...	8·62	11·79	16·33	36·56	18·32	
2, 4-D	...	8·33	53·17	100·00	100·00	65·37	
NAA	...	9·14	63·34	100·00	100·00	68·12	
IAA	...	8·88	43·66	100·00	100·00	63·14	
Average	...	7·92	27·46	51·55	70·64	...	1·09

C. D. for interaction 4·09

The noteworthy features revealed by the data are :—

(*i*) The inhibitation of uredospore germination, in general, shows a linear relationship with increasing concentration; however, the magnitude of the increase varies with the chemical.

(*ii*) Disregarding concentration variations, the results expressed as mean of all the concentrations, exhibit the order of their effectiveness as follows :

NAA > 2, 4 – D > IAA > dithane z – 78 > sulphadiazine = sulphathiazole = suplhaguanidine > fytolan = coppesan = perenox > streptomycin > wettle sulphur = penicillin = blitox – 50.

On the basis of LD 50 it is seen that synthetic phytohormones 2, 4-D and NAA are effective in checking uredospore germination even at a low concentration of 10 ppm while similar results can be achieved with IAA at 100 ppm. Moreover, IAA behaves as effectively as dithane z-78 or sulphadiazine. Rest of the chemicals are effective only at 1000 ppm with the exception of pennicillin, blitox-50 and wettle sulphur which are not toxic even at the highest concentration.

DISCUSSION

Peturson (1951) observed that 2, 4-D was more effective in checking the uredospore germination of crown rust *(Puccinia coronata)* than IAA. Ibraham (1951) studied the effect for butyl ester form of 2, 4-D on the germination of uredospores of *Puccinia graminis avenae* (races 6 and 8) and found that there was no germination in concentrations above 50 ppm. Hashioka & Morihashi (1952) observed that dithane z-78 inhibited uredospore germination in wheat and barley rusts *(Puccinia triticina* & *P. hordei)* even at low concentrations. The result obtained in the present study are in line with those on rusts of barley, wheat and oats.

SUMMARY

With a view to assess the efficiency of sulphadiazine, sulphathiazole, sulphaguanidine pennicillin, streptomycin, blitox-50, coppesan, dithane z-78, fytolan, perenox, wettle sulphur 2, 4-D, NAA & IAA as possible spray materials for *bajra* rust, a detailed investigation of the effect of these chemicals at 10, 100 & 1000 ppm on the uredospore germination was carried out in the laboratory and the data were subject to statistical analysis.

The present investigation shows that 2, 4-D and NAA are toxic at 10 ppm; sulphadiazine, IAA and dithane z-78 at 100 ppm and sulphathiazole, sulphaguanidine, streptomycin, fytolan, perenox and coppesan at 1000 ppm; however, no 'toxic' influence of pennicillin, blitox-50 or wettle sulphur was observed even at the highest concentration (1000 ppm).

ACKNOWLEDGEMENT

The authors are grateful to Dr. I. M. Rao, Associate Professor, for help in statistical lay out of the data.

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* Originals not seen : source from Review of Applied Mycology.

FUNGI OF AJMER (RAJASTHAN)-IV

By

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[Received on 12th December 1958.]

This paper is intended to record some more fungi as a part of the fungous flora of Ajmer (Rajasthan) undertaken by the senior author (Joshi 1956, 1957 & 1958 a). The collections have been kept in the Mycology Herbarium of the Botany Department, Government College, Ajmer and some interesting ones have been deposited in Herb. Crypt Indiae Orient of the Indian Agricultural Research Institute, New Delhi and Commonwealth Mycological Institute, Kew, Surrey, England.

124. *Cystopus bliti* (Biv.) de Bary (Sacc.* VII:236, B. & B , **2)

On the living leaves of *Alternanthera sessilis* (Amarantaceae). Beer, 17-8-58, Leg B. Tiagi, Mycol. Herb. No. 125 (conidial stage only).

125. *Capnodium lanosum* Che. (Uppal et al 1934).

On the living leaves of *Ficus* sp. (Moraceae), Pushkar, 20-6-57, Leg N. C. J., Mycological Herb. No. 126 (Sexual and asexual stages).

126. *Puccinia aristidicola* P. Henn. (Sacc. XIV:355, B & B: 64).

On the living leaves of *Aristida depressa* (Gramineae), Gugra Ghati, 17-9-58, Leg K. P. T. V., Mycol. Herb. No. 128 (Uredo and teleuto stages).

127. *Puccinia lateritia* Berk & Curt. (Sacc. XIV:321, B. & B. : 69)

On the living leaves of *Spermococa* sp. (Rubiaceae), 16-9-56, Leg N. C. J., Mycol. Herb. No. 129 (Uredo and teleuto stages).

128. *Melampsora larici-caprearum* Kleb. (Sacc. VII : 588, B & B : 60).

On the living leaves of *Salix tetrasperma* (Salicaceae), Pushkar, Leg. V. Sharma, 5-12-58., Mycol. Herb. No. 131 (Uredo stage only).

129. *Cerotelium fici* (Cast) Arth. (Sacc. XXIII : 790, B. & B. : 56).

On the living leaves of *Ficus glomerata* (Moraceae), Nayabazar, Leg Mrs Chand. Tunwal, 26-10-58., Myco. Herb. No. 131 (Uredo and teleuto stages).

130. *Masseeella narasimhanii* Thirumalachar (Thirumalachar 1943).

On the living leaves of *Securinegea leucopyrus* (Willd.) Muell. (=*Flueggea leucopyrus* Willd.), Euphorbiaceae, Adarshnagar, Leg N. C. J., 3-12-54., Mycol. Herb. No. 132 (Telial stage very prominent in the form of horn.).

---

*Sacc.—Saccardo, P. A ; **B. & B.—Butler, E. J. and Bisby, G. R.

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131. *Puccinia romagnoliana* Maire & Sacc. (Sacc. XXII : 374; B. & B : 73).

On the living leaves of *Cyperus* sp. (Cyperaceae), Beer, Leg V. Sharma, 7-12-58., Mycological Herberium No. 133 (Uredo and teleuto stages).

132. *Sphacelotheca monilifera* (Ell. & Everh.) Clinton (M. & T.*** : 17).

In the inflorescence of *Heteropogon contortus* L. (Gramineae), Nasirabad, 20-9-58, Leg V. Sharma, Mycol. Herb. No. 134 (Teliospores abundant).

133. *Tilletia eleusines* Syd. (M. T. : 64, Joshi 1958 c).

In the ovaries of *Eleusine verticillata* Roxb (Gramineae), Chamunda, 1-9-55, Leg N. C. J., Mycol. Herb, No. 135 (Teliospores abundant).

134. *Tilletia transvaaiensis* Zundel (M. & T.: 65 ; Joshi 1958 b).

In the inflorescence of *Eragrostiella bifaria* (Gramineae), Todgargh, 3-9-56, Leg S. Mishra, Mycol. Herb. No. 136 (Teliospores abundant).

135. *Cercospora gloriosae* Syd. (B. & B. : 142).

On the living leaves of *Gloriosa superba* (Liliaceae), Hatundi, 6-8-58 Leg Inderjeet Singh, Mycol. Herb. No. 137 (conidial stage).

136. *Cercospora hibisci* Tracy & Earle (Sacc. XIV : 1099, B & B. : 142).

On the living leaves of *Hibiscus esculentus* L. (Malvaceae), Pushkar, 20-10-58, Leg N. C. J., Mycol. Herb. No. 138 (conidial stage) ; and *H. cannabinus* (Malvaceae), Beer, 7-12-58, Mycol. Herb. No. 145 (conidial stage).

137. *Cercospora longipes* Butl. (Sacc. XXII : 1432 ; B. & B. : 142).

On the living leaves of *Saccharum officinarum* (Gramineae), Buddha Pushkar, 11-11-57, Leg N. C. J., Mycol. Herb. No. 139 (conidial stage).

138. *Cercospora jasminicola* Muller & Chupp (Mundkur & Ahmad 1946).

On the living leaves of *Jasminum* sp. (Oleaceae), Govt. College Ajmer, Botanical garden. Ajmer, 29-9-58, Leg K. P. T. V., Mycol. Herb. No. 140 (conidial stage).

139. *Cercospora achyranthes* Sydow (Patel et al 1949).

On the living leaves of *Achyranthes aspera* (Amarantaceae), 16-9-56, Leg N. C. J., Mycol. Herb. No. 141 (conidial stage).

140. *Cercospora feuilleaboisii* Sacc. (Uppal et al 1934)

On the living leaves of *Solanum melongena* (Solanaceae), Lohagal village, 17-10-57, Leg N. C. J., Mycol. Herb. No. 142 (conidial stage only).

141. *Cercospora withaniae* (Mundkur & Ahmad 1946).

On the living leaves of *Withania somnifera* (Solanaceae), Bot. garden, Govt. College, Ajmer, 10-8-57., Mycol. Herb. No. 143 (conidial stage).

***M. & T. - Mundkur B. B. & Thirumalachar, M. J.

142. *Cercosporella peristrophes* Syd. (B. & B.: 32).

On the living leaves of *Peristrophe bicalyculata* (Amarantaceae), Jaipur road, 19-9-58, Leg V. Sharma, Mycol. Herb. No. 146 (conidial stage only).

143. *Ramularia areola* Atk. (B. & B.: 149).

On the living leaves of *Gossypium* sp (Malvaceae), Pushkar, Leg K. P. T. V., 10-9-57, Mycol. Herb. No. 147 (conidial stage).

144. *Alternaria solani* (Ell. & Marl.) Jones & Grant (Uppal et al 1934).

On the living leaves of *Solanum melongena* L. (Solanaceae), Pushkar, 1-2-57, Leg N. C. J., Mycol. Herb. N. 148. (conidial stage).

145. *Alternaria tenuis* Nees (Joshi 1953).

On the living leaves of *Cordia myxa* L. (Boraginaceae), Daulat Bag, 11-2-54, Leg N. C. J., Mycol. Herb. No. 149 (Conidial stage).

146. *Alternaria ricini* (Yoshii) Hansford (Pawar et al 1957).

On the living leaves of *Ricinus communis* (Euphorbiaceae) Makanpura, 6-10-58, Leg K. P. T. V., Mycol. Herb. No. 150.

147. *Alternaria citri* Pierce (Uppal et al 1934).

On the living leaves of *Citrus* sp. (Rutaceae), Ramgang, 26-8-58, Mycol. Herb. No. 151 (conidial stage).

148. *Helminthosporium turcicum* Passerini (Sacc. IV: 420, B. & B.: 147).

On the living leaves of *Zea mays* (Gramineae), Leg N. C. J., Mycol Herb. No. 152 (conidial stage).

149. *Septoria arcuata* Ckc (Sacc. III:499, B. & B.: 163).

On the living leaves of *Ficus bengalensis* (Moraceae), Government T. T. College, Ajmer, 15-8-58, Leg K. P. T. V., Mycol. Herb. No. 153 (conidial stage).

SUMMARY

26 species of pathogenic fungi belonging to different groups and their respective hosts have been recorded for the first time from Ajmer and listed in this paper.

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EFFECT OF HIGH TEMPERATURE AND DESSICATION ON THE VERNALIZATION OF CERTAIN INDIAN CROP PLANTS

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Read at the 28th Annual Session of the Academy held at the University of Agra on 7th Feb, 1959.

INTRODUCTION

Reversal of vernalization through high temperature has been recorded by several workers (Lojkin, 1936 ; Efeikin, 1941 ; Purvis and Gregory, 1952 ; Verkerk, 1954 ; Waterschoot, 1957 ; Tashima, 1957 and Napp-Zinn, 1957). In addition to this Napp-Zinn observed that de-vernalization in the seeds of *Arabidopsis thaliana* could be brought about through dessication and while de-vernalization through high temperature results more effectively in the early stages of vernalization, there exists an opposite condition through that of dessication. Similar observations have also been made by Tashima (1957) on *Raphanus sativus* L. That the degree of reversal by high temperature varies with the degree of vernalization and a more stable condition is reached as the process becomes complete has been demonstrated by Purvis and Gregory (1952).

Sen and Chakravarti (1946) while working with maximally vernalized seeds of mustard recorded that there was no de-vernalization when the seeds were subjected to a temperature of 35°C for 48 hours. Schwabe (1951) also failed to record de-vernalization in chrysenthemum by subjecting the plants to temperatures of about 20-25°C. In the experiments of Sen and Chakravarti (1946), the seeds used were maximally vernalized and in the light of the observations of Purvis and Gregory referred above, the failure to record any de-vernalization in mustard might have been due to the attainment of thermostable condition of the vernalization products. In order to test this possibility, a number of experiments with partially vernalized seeds of *Brassica*, *Cicer*, *Linum* and *Lens* were undertaken at Government Hamidia College, Bhopal.

Experiments were also carried out to confirm the observations of Purvis and Gregory (1952) that on being subjected to alternating low and high temperature, the seeds of rye remained unvernalized and also of those of Highkin (1956) where he recorded that pre-vernalization treatment of pea seeds with high temperature resulted in a progressive loss in their ability to get vernalized.

MATERIAL AND METHODS

Experiments were undertaken with the seeds of *Brassica campestris* L., T. 10 S. 13 ; *Cicer aristinum* L., T. 87 ; *Linum usitatissimum* L. T., N. P. 9 and *Lens esculenta* Moench var. Ample.

Effect of alternating high and low temperature on vernalization was studied on the seeds of *Brassica* that were soaked for 6 hours at the room temperature and then vernalized at temperatures varying between 5° and 7°C for 24 hours. After this they were removed, spread over a sheet of blotting paper and allowed to dry for 48 hours inside an incubator maintained at the temperature of 35°C. Dry seeds were then taken out, resoaked so as to restore more or less the original water content and vernalized. This alternate subjection to low and high temperature was continued for a period of 45 days after which the unsplit seeds were sown in pots along with the normal ones.

To determine the effect of pre-vernalization high temperature treatment, seeds of all the four plants soaked for 8 hours at 30°C were freed from excess moisture and kept for 48 hours in Petri dishes lined with mosit filter paper in an incubator maintained at the temperature of 35°C. Most of them germinated during treatment. These along with the seeds germinated to the same stage of development at the room temperature were kept in the refrigerator in Petri dish moist-chambers for different periods at temperatures varying between 5° to 8°C. These seeds were then sown in pots along with controls which consisted of ones germinated both at the room temperature and at 35°C to similar states of physical development.

For post-vernalization treatments, sprouted seeds chilled for various periods were kept for 48 hours in Petri dish chambers at the temperature of 35°C in the case of *Brassica* and *Linum* and at 40°C in the case of *Cicer* and *Lens*. These seeds were sown along with (*i*) ones vernalized for the same period but not subjected to high temperature (*ii*) ones maximally vernalized and (*iii*) controls sprouted to more or less the same extent.

In *Brassica* and *Linum* records of both the number of leaves developed prior to flowering and the time taken for anthesis and in the other two plants only of anthesis were kept.

EXPERIMENTAL RESULTS

Plants raised from seeds subjected to alternate low and high temperature (sown on October 4, 1954) flowered at the average leaf number of 10·4 as against that of 18·6 in the controls, thereby showing that the substance or substances formed in the seeds of *Brassica* during low temperature treatment is thermostable.

Data obtained for pre-vernalization high temperature treatment are presented in table I, a reference to which will bring out the fact that in none of the cases there has been any significant change in the time of flowering of plants raised from both normal and vernalized seeds subjected to a pre-treatment with high temperature. Thus it may be concluded that this treatment does not lead to any loss in the capacity of the seeds experimented upon to get subsequently vernalized and in this respect they resemble seeds of Bullock's winter bean, which when germinated at temperature upto 30°C for as long as 12 days remained vernalizable (Evans, 1957).

Several experiments were carried out to determine the effect of post-vernalization high temperature treatment on the flowering of *Brassica* yielding practically similar results. Data for one such experiment is presented in table II. It would be seen that there has been no significant devernalization in partially vernalized seeds of mustard due to their being subjected to a high temperature.

Results of a similar experiment with *Linum*, *Lens* and *Cicer* are presented in table III. A comparison of the vegetative cycles of plants raised from seeds vernalized for 44 days, 14 days and control will reveal that chilling for 14 days has resulted in an incomplete vernalization. In none of the plants, however, subjection of such seeds to high temperature has led to any devernalization.

TABLE I

Effect of pre-vernalization high temperature treatment on the flowering of *Brassica*, *Linum*, *Lens* and *Cicer*.

Date of sowing : Oct. 1, 1957 Number of plants per treatment : 10

Period of vernalization : Mustard, 15 days ; Rest, 36 days

Crop	V* or C	Pretreated?	Time for anthesis in days	Delay due to pre-treatment	C. D. at 5% level	Leaf No.	Increase due to pre-treatment	C. D. at 5% level
Brassica	V	Yes	31·3	0·4	2·3	8·8	−0·1	0·3
	V	No	30·9			8·9		
	C	Yes	52·3	1·2		18·5	0·4	
	C	No	51·1			18·1		
Linum	V	Yes	42·1	2·3	3·4	53·0	−2·8	10·4
	V	No	39·8			55·8		
	C	Yes	67·9	1·6		124·1	8·3	
	C	No	66·3			115·8		
Lens	V	Yes	74·6	−4·3	4·3			
	V	No	78·9					
	C	Yes	109·3	3·0				
	C	No	97·3					
Cicer	V	Yes	41·8	−1·3	4·6			
	V	No	43·1					
	C	Yes	62·5	−3·3				
	C	No	65·8					

* V—Vernalized C—Control

TABLE II

Effect of post-vernalization high temperature treatment of partially vernalized seeds of *Brassica* on the time taken for anthesis.

Date of sowing : Oct. 5, 1957 Number of plants per treatment : 10

Treatment	Time for anthesis in days	Earliness over corresponding heat treatment	Leaf No.	Decrease over corresponding heat treatment
18 days' chilling plus heat	28·3	—	8·7	—
18 days' chilling only	29·2	−0·9	8·5	−0·2
12 days' chilling plus heat	32·6	—	11·2	—
12 days' chilling only	31·9	0·7	11·6	0·4
8 days' chilling plus heat	37·6	—	13·3	—
8 days' chilling only	38·8	−1·2	13·7	−0·4
4 days' chilling plus heat	44·6	—	15·2	—
4 days' chilling only	43·9	0·7	15·7	−0·5
High temperature control	48·3	—	18·7	—
Ordinary control	49·8	−1·5	18·3	0·4

C. D. at 5% level : Anthesis, 1·6

Leaf No., 0·8

TABLE III

Effect of post-vernalization high temperature treatment of partially vernalized seed of *Linum*, *Lens* and *Cicer* on the time taken for anthesis in days.

Date of sowing : Nov. 16, 1956 No. of plants per treatment : 10

Crop	Vernalized for 44 days	Control	Vernalized for 14 days			C. D. at 5% level
			Room temp.	High temp.	Delay over room temp.	
Linum	46·9	74·6	60·0	61·4	1·4	3·2
Lens	64·9	96·6	85·9	90·8	4·9	5·8
Cicer	43·5	68·9	52·3	48·5	−3·8	4·9

DISCUSSION

An understanding of the mechanism of vernalization in plants with an obligate low temperature requirement is based chiefly on the observation that vernalization is reversed by treatment with high temperature. Practically all the plants where such de-vernalization has been recorded *i. e.* winter cereals (Purvis and Gregory, 1952), Japanese radish (Tashima, 1957), *Arabidopsis* (Napp-Zinn, 1957), Brussels sprouts (Verkerk, 1954) and *Dianthus* (Waterschoot, 1957) are ones which normally flower after experiencing the severe cold of the west, with temperatures below freezing during the winter months. There exists no parallelism between the growth conditions of these plants with the ones in India with non-obligatory low temperature requirement as they are hardly subjected to a temperature below zero during the entire period of their growth.

The difference in the nature of the response between these two groups of plants as referred above might be due to their ecological adaptations to different temperatures and photoperiods. On account of their growth in a comparatively warmer climate, the phase of synthesis of thermo-labile substance or substances have completely been eliminated from the life-histories of the Indian varieties of *Brassica*, *Linum*, *Lens* and *Cicer*. The minimum temperature at which de-vernalization starts in certain temperate plants like rye (12°C) and winter wheat (15°C) are temperatures not uncommon in India during the earlier part of the winter sowing season.

Experiments of Sen and Chakravarti (1942) where partially and maximally vernalized seeds of mustard were subjected to prolonged dessication and the present one where the seeds were subjected to alternate low and high temperature without any devernalization indicate that a condition similar to the one present in rye (Gregory and Purvis, 1938, and Purvis and Gregory, 1952), *Arabidopsis* (Napp-Zinn, 1957) and Japanese radish (Tashima, 1957) does not exist in mustard.

SUMMARY AND CONCLUSIONS

The present investigation has been undertaken to determine whether vernalization could be prevented when (*i*) a 24 hours low temperature (5° to 7°C) treatment of soaked seeds of *Brassica campestris* L. is alternated with their dessication at a temperature of 35°C for 48 hours over a total period of 45 days and (*ii*) soaked seeds of *Brassica campestris* L., *Cicer arietinum* L., *Linum usitatissimum* L. and *Lens esculenta* Moench are subjected before chilling to a temperature of 35°C for 48 hours and also whether devernalization results when partially vernalized seeds of *Brassica* and *Linum* are subjected to a temperature of 35°C and those of *Cicer* and *Lens* to 40°C for a period of 48 hours.

Treated seeds were sown in pots along with their corresponding controls. Records of the average time taken for anthesis were kept for all the four plants. In *Brassica* and *Lens*, the total number of leaves developed on the axis prior to flowering was also counted. None of the treatments referred above interfered with the process of vernalization.

It is concluded that the difference between the Indian crop plants on the one hand and plants like winter cereals, Japanese radish, *Arabidopsis*, Brussels sprouts, *Dianthus* etc. of the cooler countries on the other, as regards the effect of high temperature on vernalization might be due to their ecological adaptations. On account of the growth of the former in a comparatively warmer climate, the phase of synthesis of thermolabile substance or substances during the process of chilling seems to have been eliminated.

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"FURTHER OBSERVATIONS ON ARTYFECHINOSTOMUM SUFRARTYFEX (LANE) BHALERAO, 1931 (TREMATODA: ECHINOSTOMATIDAE) WITH A NOTE ON ITS SYSTEMATIC POSITION"

By

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[Received on 16th March, 1959]

INTRODUCTION

The digenetic trematode which forms the basis of this study belongs to the family Echinostomatidae. The parasites were found in large numbers attached to the small intestine of pigs at Jabalpur, appearing as small red, punctate objects, and on being examined were found to represent the species *Paryphostomum sufrartyfex* Bhalerao, 1931. The species *P. sufrartyfex* was discovered by Lane on September 1, 1914, in the body of a small Assamese girl. He included this species under his new genus *Artyfechinostomum*. Subsequently to the publication of Lane's paper, some doubt was expressed as to the validity of his genus and the species described by Lane. Leiper and Odhner were led to think that *A. sufrartyfex* (Lane, 1915) is a synonym of *Echinostomum malayanum* (Leiper, 1911). But Lane (1917) pointed out clearly that his species was different from the latter form. Fuhrman (1928) and Faust (1929) supported him that the later genus was not identical to Echinostoma. Bhalerao (1931) redescribed *A. sufrartyfex* (Lane, 1915) from the material obtained from pigs at Calcutta and considered *Artyfechinostomum* to be a synonym of *Paryphostomum* (Dietz, (1909). Mendheim (1943), however, retained the genus *Artyfechinostomum* with two species *A. sufrartyfex* and *A. malayanum*, and included the genus under the subfamily Echinostominae. The records about the incidence of the above parasite *Paryphostomum sufrartyfex* were also reported by Reddy and Varmah (1950) from a boy and by Ramanujachari and Alwar (1954 from pigs in Madras State and were inadequately described by them. In another recent report Rai and Ahluwalia (1958) have described the species under the name *A. sufrartyfex* with 43 collar spines arranged in two rows and having a coiled and tubular vesicula seminalis.

Thus, it appears, that there still exists a great controversy regarding its morphology and taxonomic position. The present author, after comparing the description of previous workers notably Rai and Ahluwalia, feels that some points regarding the number and arrangement of collar spines, extent and structure of cirrus sac particularly seminal vesicle, have to be added to the accounts given by them.

It is, therefore, proposed that the two genera *Artyfechinostomum* and *Paryphostomum* (Dietz) which resemble each other, should be placed under the subfamily *Paryphostominae* Mendheim, 1943 and the species *E. malayanum* (Leiper, 1911), *P. indicum* (*Bhalerao*, 1931) and *P. mehrai* (Jain, 1957) be transferred under the genus *Artyfechinostomum* with *A. sufrartyfex* as the type species.

The material for the present study was obtained from the intestine of infected pigs at Jabalpur. Worms were studied alive in normal salt solution. For preservation they were first washed with water and then fixed in hot Bouin's fluid, formed by mixing formaldehyde 40%, pure acetic acid and saturated picric acid in the ratio of 25 : 5 : 75. The next day the fixed specimens for entire mounts were carefully removed from the slide, washed in running water and the yellow colour of Bouin's fluid was washed away in 70% alcohol and the remaining was completely removed by chlorinated 70% alcohol.

Specimens for whole mounts were stained in acid carmine, Haemalum, Delafield's haematoxylin. The adults, stained in Delafield's haematoxyline and counter stained with Eosine, gave very good results for the demonstration of collar spines.

MORPHOLOGY OF THE ADULT *A. SUFRARTYFEX* (LANE, 1915)

Host : Pigs (*Sus scrofa domestica*)

Location : Intestine.

Locality : Jabalpur (India)

External characters:

The adults (Fig. 1) are elongated, flat and are some what narrow in the preacetabular region while behind it the sides of the body are nearly parallel. The posterior end is almost rounded. Mature and well flattened specimens measure 12·96 m. m. in length and 4·45 m. m. in breadth in the testicular region. At the anterior extremity the body forms the head collar which is strongly developed. The collar (Fig. 2) is armed with 42 spines arranged in a single row uninterrupted dorsally. The spines in the end group are a little larger than those in the marginal ones. One of the spines in the end group is more stout and striking which measures 0·082 × 0·0246 m. m. while others measure 0·0697 – 0·0779 × 0·0205 m. m. The other marginal spines measure 0·0533 – 0·0615 × 0·0164 m. m. in size.

The integument:

A fairly uniform cuticle covers the entire body. The integument is thickly covered by small cuticular spines arranged in transverse rows directed backwardly. These spines gradually decrease in number from the level of the ventral sucker till they disappear completely in the testicular region. The spines are deeply embedded in the cuticle, are of uniform size, and measure 0·041 – 0·0656 × 0·0205 m. m. in size.

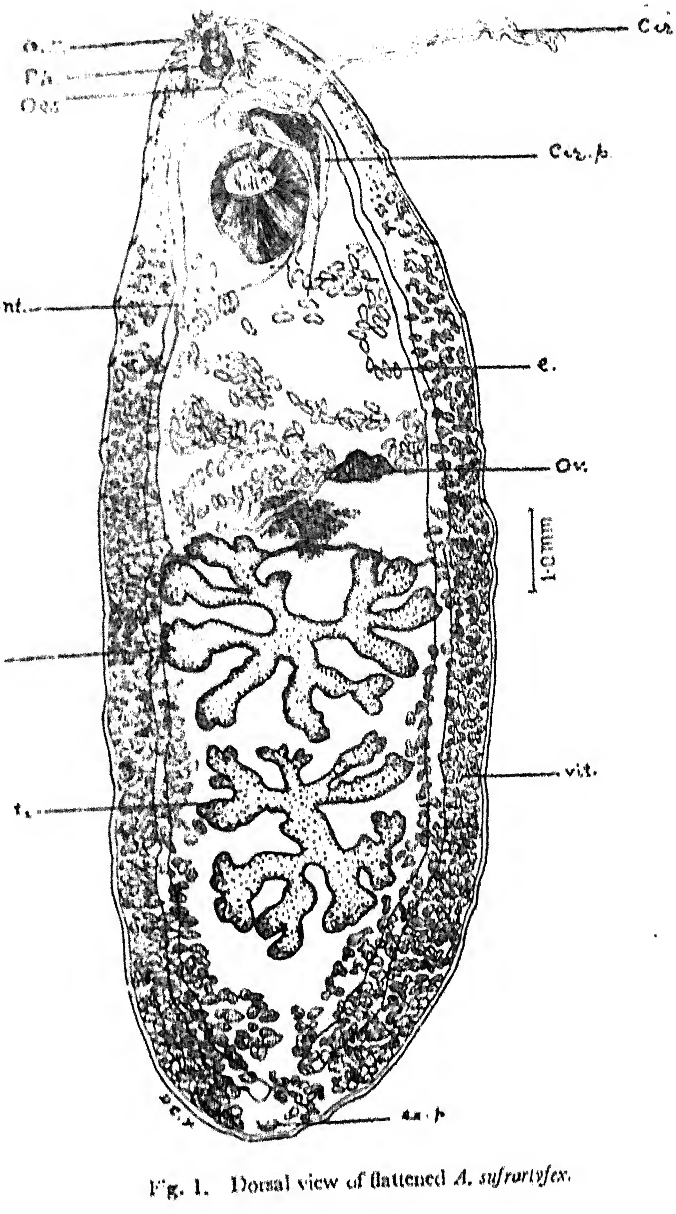

Fig. 1. Dorsal view of flattened *A. sufrartyfex.*

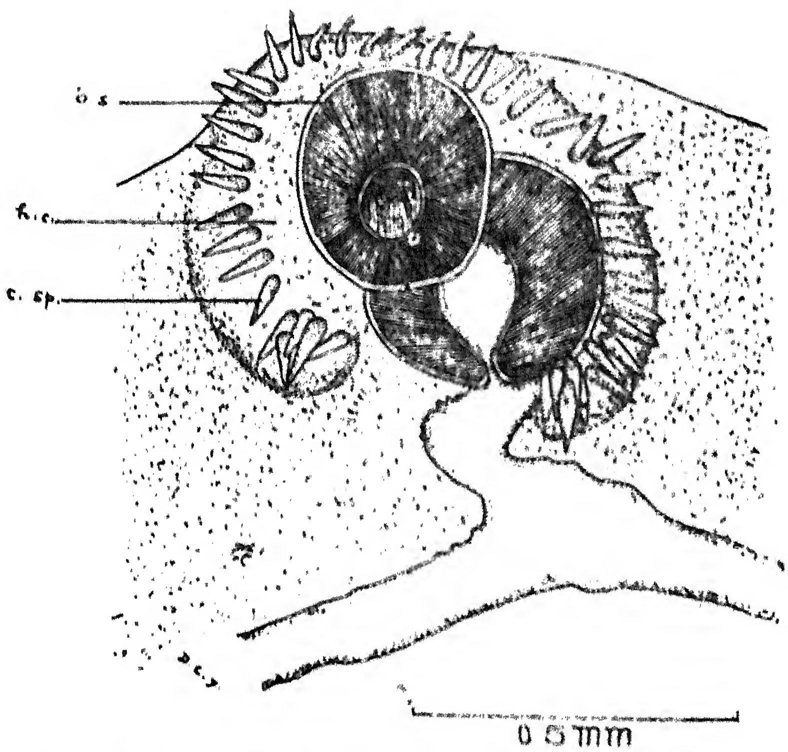

Fig. 2. Head collar showing the number and arrangement of collar spines.

Musculature:

The body has developed the usual type of Trematode musculature. A singly arranged layer of circular muscle fibers lie immediately beneath the basement membrane. Beneath the circular muscles lie the thick layer of longitudinal muscle-fibers followed internally by the diagonal muscle fibers. The large cutaneous gland cells occur below the diagonal muscular layer and are roughly pear-shaped with the narrow end directed towards the outer surface. These have a definite outline, deeply staining with finely granular contents.

Suckers:

The acetabulum is well developed, muscular, and measures 1·65 m.m. × 1·275 m. m. in diameter, with a roughly pear-shaped outline. Its position in relation to the length of body varies with the size of the worm. The length of the acetabulum is about 1/7th of the body length. The cavity of the acetabulum is lined with a layer of cuticle continuous with that of the body wall. Under the cuticle is a thin fiberous membrane which separates the musculature of the sucker from it. This is followed by a thick strand of radial muscle fibers. Underneath the radial muscle fibers lies the internal membrane closely adjacent to the parenchyma.

The oral sucker is small, rounded and sub-terminal measuring 0·0336 m. m. in diameter. The shape of the opening is usually oval. The ratio of the diameter of the oral sucker to the ventral sucker is 1 : 4. The histological structure is essentially the same as that of the ventral sucker, but the muscle fibers are much thinner.

Alimentary canal:

The mouth lies within the cavity of the oral sucker. Directly in side is the short prepharynx (0·015 – 0·09 m. m. in length), connected with the pharynx (0·351 m. m. ×0·392 m. m.) which appears oval in shape. The oral sucker and the pharynx appear to be of the same size. There is a short oesophagus, having an average length 0·225 m. m. It bifurcates to form the two intestinal caeca just infront of the ventral sucker, and extends to the posterior end of the body. Internally it is lined by a single layer of epithelial cells, which give rise to villi like projections. The musculature consists of the usual internal circular and external longitudinal layers. The caeca are attached to the body wall by fiberous bundles.

Excretory system:

The excretory pore is situated on the dorsal surface at about 0·06 m. m. distance in front of the hinder end. The excretory bladder is Y-shaped with a short elongated vesicle like median stem produced in front into two very long cornua, which extend anteriorly up to the pharynx. The median vesicle and the cornua are produced into many irregular lateral branches outside, which are further branched. All along their course, the main stem and cornua send their diverticula towards the edge of the body.

Genital system:

The gential organs occupy the most prominent position and the most space in the posterior part of the body. The male and female ducts open separately a little in front of the acetabulum.

The male genital system:

The characteristic feature of this fluke is the large deeply lobed testes situated along the median line in the middle of the posterior half of the body. There are usually four lobes in the testes which are further deeply intended. The post-testicular space measures 1·32 m. m. in a specimen of 12·99 m. m. in length.

Both vasa deferentia take their origin on the dorsal surface near the anterior end of the middle line of their respective testes. The right vas deferens arises from the posterior testis, curves round the anterior testis to run forward in a straight line as far as the cirrus-sac where it joins the left vas-deferens arising from the anterior testis. The latter occupies the similar position on the left side and passes forward, curving immediately behind the cirrus-sac to join its fellow forming the vesicula seminalis (fig. 3).

The size of the cirrus sac varies considerably from 1·725 m. m. - 4·125 m.m. × 0·636 m. m. in breadth. It lies with a slight inclination ventrally on the ventral sucker. The basal end extends either up to the middle of the ventral sucker or behind the posterior margin of the latter. The vesicula seminalis (0·975 m. m. × 0·45 m. m.) is elongated, filling the greater portion of the cirrus sac. It leads into a wide small duct in the form of a V-shaped narrow elongated tube running along the side of the cirrus sac. It opens anteriorly into the ejaculatory duct. The ejaculatory tube then enters in a long cirrus which emerges as an extensile tube. It, when not extruded, is coiled within the sac. Sections show that no part of this tube is surrounded by cells which may function as pars prostatica. Spines have also been found on the posterior of the cuticula lining the cirrus.

Female genital system:

The ovary is situated a little to the left side and is pretesticular (Fig. 1). It is nearly pear-shaped with an entire margin and measures 0·842 m.m. × 0·484 m.m. in diameter. It consists of a single layer of germ cells enclosed within a basement membrane. The germ cells at the outer peripheral region are smaller and more compact than those in the centre and posterior part of the organ. The mature ova are some what oval in shape and contain a large rounded nucleus. The shell gland mass lies a little posterior to the ovary and occupies a median position. The oviduct arising from the inner narrow end (Fig. 4) passes backwards to the right side and bulges into a small sac like structure of receptaculum seminis. The small receptaculum seminis is oval, filled with sperms. No Laurer's canal could be traced out.

The oviduct soon after receiving the small receptaculum seminis narrows into a short tube and passes to the right of the shell gland mass, where it becomes

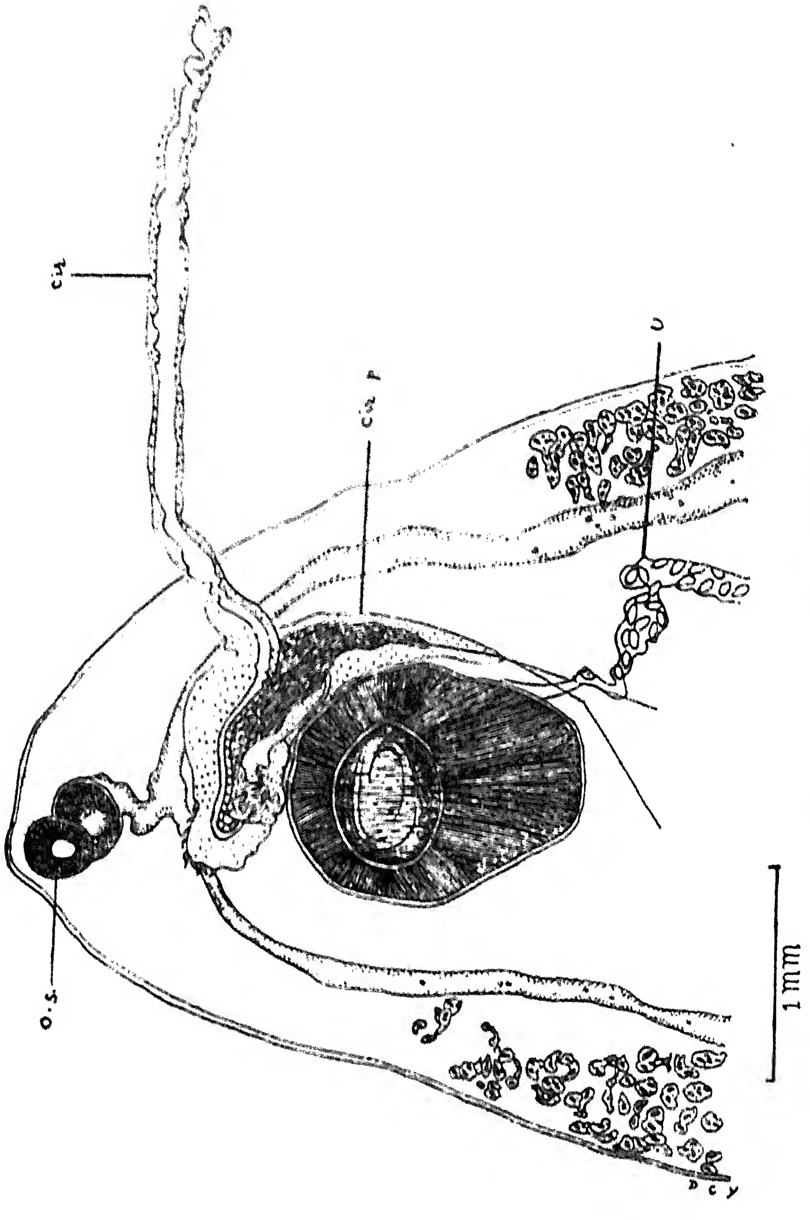

Fig. 3. Everted cirrus and the cirrus sac with its contained organs.

fairly broader and receives the broad common yolk duct of the vitelline reservoir. The shape of the compact shell gland mass is pear-shaped and is composed of a large number of cells which are closely aggregated together. The cells are quite discrete and are not enclosed within a membrane. The shell gland cells are small, and radially arranged around the ootype in which they open by their narrow ducts.

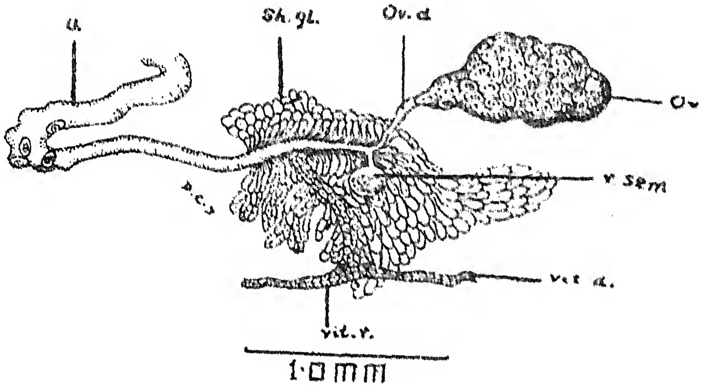

Fig. 4. Side view of the shell gland complex.

The vitellaria occupy the lateral margins of body extending from the middle of the ventral sucker to the hinder end. They over-lap the intestinal caeca in the testicular region, and practically unite with one another immediately behind the posterior testis. The vitelline follicles are pear-shaped. The vitelline ducts have the usual disposition.

The uterus arises from the right side of the ootype and has some what muscular walls. It soon passes laterally and then forwards as a wide thin walled tube which soon becomes coiled and reaches the level of the posterior end of the ventral sucker where it opens into the metraterm. The metraterm proceeds forward to open to the exterior at the female genital aperture situated slightly posterior to the male aperture.

The ova are not numerous, thin shelled, bright yellow in colour and measure 0·135 m. m. × 0·075 m. m. in size.

DISCUSSION

No end of confusion in the systematology of the species *Paryphostomum sufrartyfex* (Lane) Bhalerao, 1931, has resulted from a disregard for the original diagnosis of the genus *Artyfechinostomum* (Lane, 1915). The genus *Artyfechinostomum* was not recognised, but the species *A. sufrartyfex* was placed under the genus *Paryphostomum* (Dietz, 1909) by over looking items in the original description.

It is furthermore evident that Bhalerao (1931,476) in his description of *Paryphostomum sufrartyfex* referring to certain specimen states that it was difficult to make out any spines in the collar.

The genus *Artyfechinostomum* is differentiated from *Paryphostomum* by the presence of large number of collar spines (42 in number) and the cirrus sac being long

lying with an inclination over the ventral sucker. The body is usually elongated and the cuticle is spiny. The testes are deeply lobed and the lobes are further intended. The vitelline follicles are intracaecal in the post testicular region and approach to meet towards the median line.

The author does not think that Bhalerao (1931) was justified in considering *Artyfechinostomum* (Lane) as a synonym of *Paryphostomum* (Dietz). The genus *Paryphostomum* is characterised by the presence of small number of collar spines (27 in number) and the cirrus sac being small, dorsal to the ventral sucker.

The body is small and the cuticle is spiny in the preacetabulum region. The vitelline follicles are intracaecal in the post testicular region but do not meet in the median line.

These points being of sufficient importance to distinguish the two genera, it will be instructive to compare these two genera in a tabular form.

TABLE I

	Artyfechinostomum Lane, 1915	*Paryphostomum* Dietz, 1909.
Body	Elongated	Small.
Collar	Not united ventrally.	Not united ventrally.
Collar spines	42 in a single row or double rows.	27 in a single row or double rows.
Vitellaria	Extend from hinder end-of ventral sucker to the posterior end of body and confluent in the post-testicular region.	Extend from hinder end of ventral sucker to the posterior end of body and approach to meet in the median line in the post-testicular region.
Testes	Deeply lobed	Lobed
Cirrus sac	Extends posterior to ventral sucker.	Dorsal to ventral-sucker.
Cirrus	With spines	Spines absent
Vesicula-Seminalis.	Tubular	Tubular

In the light of the facts brought forth here it is necessary to consider the two genera separate from each other and place them under the subfamily *Paryphostominae* Mendheim, 1913.

In the table II are compared the known species of *Artyfechinostomum* with the form *A. sufrartyfex.*

TABLE II

Comparative table of the species of *Artyfechinostomum*

	A. sufrartyfex	*A. malayanum*	*A. indicum*	*A. mehrai*
Host	(*i*) Human beings (*ii*) Pigs.	(*i*) Human beings	(*i*) Uromastix-hardwickii	(*i*) White rats
Locality	India (Assam, Calcutta, Madras, Aligarh Jabalpur).	Malaya States.	Northern India	Northern India
Size (m. m.)	9×2·5 (Lane) 12·96×4·45 (author)	12×3	7·5-8·1×1·7-2	8·36×1·6
No. of spines	42	42	42	43
Marginal spines	32	36	32	39
Terminal spines	5 on each side	3 on each side.	5 on each side	2 on each side
Oral sucker diameter (m. m.)	0·2-0·3 (Lane) 0·336 (author)	Very small	0·18	0·247
Ventral sucker (m. m.)	1·65×1·275	0·9×0·75	0·62×0·068	0·96×0·83
Ratio of oral sucker to ventral sucker.	1 : 4.	—	1 : 3·5	1 : 3·5
Oesophagus (m. m.)	0·225	0·04	0·25	0·22
Commencement of vitellaria.	From the middle of the ventral sucker.	From the posterior border of ventral sucker.	From the middle-of the ventral-sucker.	Form the posterior border of the ventral sucker.
Eggs. (m. m.)	Numerous	Few	Few	Numerous
	0·09×0·075 (Lane)	—	0·04–0·097	0·096×0·064
	0·135—0·075 (author)		0·033—0·072	

It is evident from the above table that the present form differs from all other species transferred under the genus *Artyfechinostomum*.

ACKNOWLEDGEMENT

The author is greatly indebted to Dr. G. P. Jain, for his valuable guidance under whom this work was conducted. He also wishes to express his sincere thanks to Prof. U. D. Mukerji, Principal, Mahakoshal Mahavidyalaya, Jabalpur for extending him the necessary laboratory facilities.

EXPLANATION OF PLATES

All drawings accompanied by a reference line were made with the aid of a camera lucida and details filled in at the same magnification.

ABBREVIATIONS

Acet, Acetabulum; Cir, Cirrus; Cir. p., Cirrus pouch; C. sp., Collar spines; e., Eggs; ex. p., Excretory pore; h. c., Head collar; int., Intestinal caeca; Oes., Oesophagus; O. S., Oral sucker; Ov., Ovary; Ov. d., Oviduct; Ph., Pharynx; p. Ph., Prepharynx; r. sem., Receptaculum seminis; Sh. gl., Shell gland; t_1, Anterior testis; t_2, Posterior testis; U., Uterus; Vit., Vitelline follicles; Vit. d., Vitelline duct; Vit. r., Vitelline reservoir; V. sem., Vesicula seminalis.

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PHYSIOLOGICAL STUDIES ON SALT-TOLERANCE IN CROP PLANTS

VI. EFFECT OF NaCl AND Na_2CO_3 ON GRAIN QUALITY IN WHEAT*

By

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Read at the 28th Annual Session of the Academy held at the University of Agra on 8th February 1959

INTRODUCTION

Crop growth in saline or alkaline areas is generally poor leading to decreased production of straw and seed. The seeds produced are of inferior quality. However, analysis of seeds, in order to evaluate the influence of salinity or alkalinity on its chemical composition does not seem to have been investigated so far. Thus, in the present study, analysis of wheat grains, obtained from plants grown with optimum water supply in pots with 0·1% NaCl or 0·03% Na_2CO_3, added to the soil at the time of sowing, were carried out.

METHODS AND MATERIAL

Complete analysis of wheat C. 591 grains was carried out according to the conventional 'A.O.A.C.' methods for determining the quality of food-stuffs (grains). The following constituents were determined : percentage moisture, proteins, fats, fibre, ash and carbohydrates.

Further, fractions of 'total-nitrogen' (protein-N and rest-N) were estimated by Macro-kjeldahl method ; and fractions of carbohydrates, reducing and invert sugars by Munson-Walker Bertrand method as suggested by Loomis and Shull (1937) and starches by the procedure adopted by Wright (1938), were also investigated.

The grains for the above analysis were obtained from the plants grown in pots (9″×9″) in soil containing either 0·1% NaCl or 0·03% Na_2CO_3 (on air dry soil basis) ; the salt was added at the time of sowing. Grains from the 'no-salt-set' served as control. Optimum water-supply—from field capacity (about 25%) to 17% soil moisture—was maintained in all the pots. Observations on grain analysis were recorded in duplicates.

RESULTS

Data on chemical analysis of the grains for the influence of the two salts (NaCl and Na_2CO_3) are expressed as percentage on air-dry-weight of the grains, and are included in table 1 and also represented by Figures 1A and 2A.

* Part of the thesis approved for the Ph. D. degree of the Agra University.

TABLE I

Influence of 0·1% NaCl or 0·03% Na_2CO_3 added to the soil at the sowing time on chemical composition of wheat C. 591 grains.

(% on air-dry-seeds)

Chemical constituent	Control (No salt-set)	0·1% NaCl	0·03% Na_2CO_3
Moisture	11·91	11·97	9·03
Fibre	2·64	2·99	2·73
Ash	2·86	2·82	2·91
Fats	1·59	1·41	2·28
Proteins	11·36	14·03	14·40
Carbohydrates	70·64	66·78	68·65

It is indicated that soil dressing with 0·1% NaCl at the time of sowing resulted in the production of grains which were higher in protein-content but lower in carbohydrates. Grains harvested from the carbonate-set also exhibited an increase in protein-content and in fats, but a decrease in moisture content and also in carbohydrates.

Influence of the two salts on the fractions of carbohydrate are expressed as percentage on oven-dry seeds in table IIA and percentage on total carbohydrates in table IIB and in histograms 1B and 2B.

TABLE II

Effect of 0·1% NaCl or 0·03% Na_2CO_3, added to the soil at the sowing time, on fractions of carbohydrates in wheat C. 591 grains.

Treatment	Reducing sugars	Invert sugars	Starches
A : % on oven-dry seeds.			
Control	0·60	7·82	65·57
0·1% NaCl	0·47	1·82	71·15
0·03% Na_2CO_3	0·13	1·18	67·32
B : % on toal carbohydrates.			
Control	0·75	9·9	81·5
0·1% NaCl	0·55	2·3	89·4
0·03% Na_2CO_3	0·15	1·5	88·2

From the above data, it is clear that both reducing and invert sugars are decreased in salt-fed plants while starches are increased.

Fractions of total-nitrogen are expressed in table III and also in figures 1C and 2C as percentage on oven-dry seeds.

TABLE III

Effect of 0·1% NaCl or 0·03% Na_2CO_3, added to the soil at the sowing time, on fractions of nitrogen in grains of wheat C. 591.

(% on oven dry seeds)

Treatment	Total Nitrogen	Protein Nitrogen	Rest Nitrogen
Control	3·07	1·78	1·29
0·1% NaCl	3·01	2·19	0·82
0·03% Na_2CO_3	3·16	2·25	0·91

Percentage total-nitrogen was not altered in the grains harvested from the chloride-or carbonate-set but protein-nitrogen was increased.

DISCUSSION

Before attempting a discussion of the results, it would be worthwhile to compare the results of the present study on the chemical composition of the wheat C. 591 grains obtained from the plants grown in normal soil (no-salt set) with the analysis of wheat grains given by Aiyer (1947).

Name of the worker	Moisture	Fibre	Ash	Fats	Proteins	Carbohydrates
Present data	11·9	2·6	2·9	1·6	11·4	70·6
Church	12·5	2·7	1·7	1·2	13·5	68·4
Leather	12·2	1·7	1·8	1·7	9·9	72·7
—Do—	12·9	1·5	2·4	2·1	8·9	72·7

The results of the present study agree fairly well with those of the other workers. The small variations can be attributed to the variety of wheat under study and also to the conditions of growth. Details regarding these two aspects for the results of Church and Leather are not available.

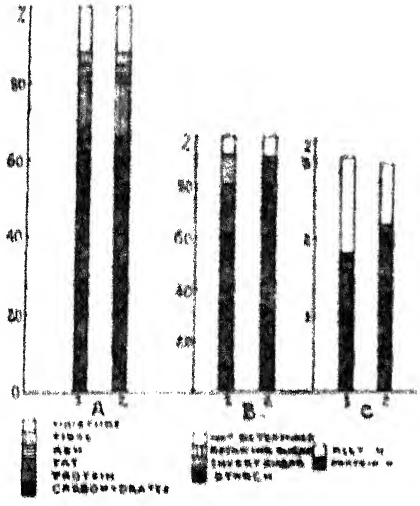

FIG. 1

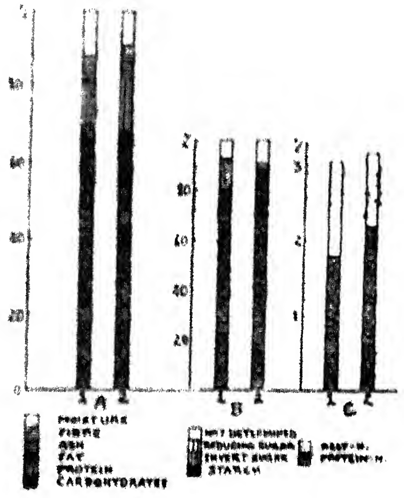

FIG. 2

EXPLANATION OF THE FIGURES

Fig. 1. Effect of 0·1% NaCl, added to the soil, on the quality of grains of Wheat C. 591.

1, 2 : 0% and 0·1% NaCl (on air-dry soil basis), added to the soil at the sowing time.

A : Chemical analysis of the grains (Percentage on air-dry soil).

B : Carbohydrate fractions of the grains (Percentage on total carbohydrates present in the grains).

C : Nitrogen fractions of the grains (Percentage on oven-dry seeds).

Fig. 2. Effect of 0·03% Na CO_3, added to the soil, on the quality of grains of Wheat C. 501.

1, 2: 0% and 0·03% Na_2CO_3 (on air-dry soil basis), added to the soil at the sowing time.

A : Chemical analysis of the grains (Percentage on air-dry soil).

B : Carbohydrate fractions of the grains (percentage on total carbohydrates present in the grains).

C : Nitrogen fractions of the grains (Percentage on oven-dry seeds).

Reverting now to the influence of NaCl or Na_2CO_3 on the chemical composition of wheat grains, the following points are noteworthy :

(i) Sodium chloride leads to a decrease of carbohydrates but increase in protein-nitrogen of the wheat grains. Among the carbohydrates, sugars (reducing and invert) are decreased while starches are increased.

(ii) Sodium carbonate results in a decrease of carbohydrates and also of moisture-content, but increases the protein-nitrogen and also fats. Fractions of carbohydrates are similarily affected as by chloride.

Thus the effect of the two salts on grain composition seems to be similar, but the carbonate seems to be more effective than the chloride regarding the sugars (reducing and invert). Bhardwaj and Rao (1958) have reported the influence of the above two salts on early seedling metabolism in wheat. It would be interesting to compare the above results with those on 'seedling metabolism', and so they are summarized in table IV.

TABLE IV

Effect of NaCl and $NaCO_3$ on chemical composition of seedlings (96 hours old) and of grains of wheat C. 591.

(% on respective control)

Observation	Reducing sugars	Invert sugars	Protein-nitrogen
NaCl supply :—			
Seedling analysis	59	100	79
Grain analysis	78	24	123
Na_2CO_3 supply :—			
Seedling analysis	49	45	73
Grain analysis	22	15	126

Note :—The doses of the salts supplied to the seedlings in the metabolism experiments are 0·6% and 0·2% solutions of NaCl and Na_2CO_3 respectively. The grains for analysis were obtained from the plants grown in soil containing 0·1% NaCl or 0·03% Na_2CO_3 (on air-dry basis). However, when values for salt-concentration are calculated on soil solution basis (17% soil-moisture level), they are nearly equal to those used for the seedling studies.

The above data reveals that :

(i) Reducing sugars are depressed by the two salts at the seedling stage (96 hours after sowing); the depressing influence is also seen in the grains produced ; carbonate is relatively more depressing than chloride in both the cases. Thus the results on grain analysis indicate that the two salts in some way interfere with the carbohydrate metabolism,

The results on chloride effect are supported by the findings of Gauch and Eaton (1942) that, by accumulation of chloride ion, the sucrose content is markedly affected ; of Baslavskaja (1936), who says that the accumulation of chloride disturbs the photosynthetic activity leading to reduction of total carbohydrates ; and of Garner, *et al* (1930), that the amylolytic activity is disturbed. It is not clear whether the carbonate effect can also be explained on the above basis.

(*ii*) Protein nitrogen is lowered at the seedling stage, but the effect appears to be reversed at maturity as the grains produced were richer in protein-nitrogen : the differences due to the two salts are small. Apparently in wheat seedlings hydrolysis of the reserved protein is accelerated by the salts while in the maturing grain the synthesis is facilitated.

From the above results, it can be concluded that :

(*i*) A supply of chloride or carbonate brings about a disturbance in carbohydrate metabolism and protein synthesis.

(*ii*) Carbohydrates, particularly reducing sugars, can offer a fair indication regarding the depressing effect of chloride or carbonate.

SUMMARY

Grains of wheat from the harvest of plants grown with optimum water-supply in pot culture in soil to which NaCl or Na_2CO_3 was added at the time of sowing at 0·1% or 0·03% (on air-dry basis) were analysed for their chemical composition following the 'A.O.A.C.' methods.

Addition of 0·1% NaCl resulted in an increase of proteins and in a decrease of total carbohydrates, both reducing and invert sugars were lowered but starches were increased. The carbonate (0·03%) increased the protein and fat content of the grains, while moisture content and carbohydrates were lowered ; reducing and invert sugars were depressed but starches were increased.

It is thus evident that the influence of the chloride or carbonate added to the soil even at the time of sowing, persists upto maturity. NaCl appears to interfere with the carbohydrate and protein metabolism, while Na_2CO_3 seems to influence, in addition, the fat metabolism too.

ACKNOWLEDGEMENTS

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STUDIES ON FRESHWATER PLANKTON—PART III*

QUALITATIVE COMPOSITION AND SEASONAL FLUCTUATIONS IN PLANKTON COMPONENTS

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ABSTRACT

The present paper gives a more or less complete picture of the general characteristics of North Indian plankton of lentic freshwaters based on regular weekly collections for two years. The seasonal distribution of the plankton and the fluctuations of the phytoplankton and zooplankton components are given in detail, and are, to our knowledge, given fully for the first time for Indian freshwaters. This plankton picture has also been compared with the pictures obtained from colder countries and with plankton pictures of the sea.

INTRODUCTION

Although the knowledge that microscopic organisms are present in water extends back from the days of Leeuwenhoek (1632-1723), the actual studies on plankton started much later. It does not appear to have been finally decided as to who should be credited for the discovery of plankton. Needham and Lloyd (1930) however attribute it to Liljeborg and Sars who, while drawing fine nets through the waters of the Baltic collected mostly microscopic fauna and flora. In spite of the fact that Johannes Muller (1845) and later Peter Erasmus Muller began the studies of plankton and discovered some micro-crustacea, it was not until Victor Hensen (1887) that the term 'plankton' was proposed to include all minute anin als, plants and debris which were found suspended in natural water ("Alles was in wasser treibt"). Haeckel used it in a still broader sense and included pelagic life of all kinds, large and small. However Hensen's definition of this term has become universal. This was soon extended to cover all assemblages of such small organisms which float or swim feebly and are carried about by the water currents or that floating universe of minute plants and animals which inhabit the open waters. Kolkwitz (1912) defined the term as the natural community of those organisms that are normally living in water and are passively carried along by currents. Rylov (1922) while discussing the forms which come under the term plankton, used the term 'obligoplankton' referring to true plankton only and 'facultative plankton' for those forms found in both limnetic and littoral regions and he stated that pelagic organisms are not the same as plankton, for plankton may be both pelagic and littoral. Eddy (1934) applied the term plankton to an aggregation of the organisms constituting all microscopic forms found in open waters. A more common definition includes those forms with little or no resistence to current living a free-floating or suspended existence in open or pelagic water. Griffith (1923) has classified plankton algae in terms of ecological features prevalent in the habitat. And from such attempts terms as rheoplankton (river), benthoplankton (shallow pond), limnoplankton (deep pond), helioplankton (pond) and many others have come out.

*With *eight* plates.

Plankton is universally reported from almost all natural waters irrespective of latitude and altitude. A good deal of research work has been put in by distinguished limnologists in various parts of the world and a large amount of literature has accumulated on the subject. In India the studies made on plankton, have been mostly confined to either marine forms on our coasts or to brackish waters. Some investigations on similar lines made in Khewera Gorge, Punjab (Pruthi, 1933), and in the Hoogly river (Dutta *et al* 1954) are also for the salt and esturine waters. No doubt, the bionomics of some freshwater organisms have been reported from a tank in Calcutta (Sewell, 1934) but neither any systematic qualitative or quantitative data for the plankton nor the peak periods or the fluctuations of the crop have been referred to.

Recent observations made on the plankton in South Indian fresh waters by Ganapati (1943) and Chacko and Kuromb (1954) along with those recorded from nursery ponds in Orissa Alikunhi *et al* (1955) are mostly causual and of short duration. As so aptly put by Annandale (1918) "*If the plankton studies are to be by made satisfactorily in any freshwater body then the collections and observations should be made regularly at all seasons, as so many organisms are plastic and vary greatly with the environmental conditions; and therefore the description of stray samples as noted by some workers are liable to obscure rather than to elucidate the biology of the given water.*" And as such it would not be an exaggeration to say that no real scientific data on freshwater plankton are available for freshwater bodies of India in general and Uttar Pradesh in particular. Das and Srivastava (1955, 1956 A and B) have given some quantitative data on plankton and the physico-chemical condition of water. In the present contribution an attempt has been made to give comprehensive qualitative data on freshwater plankton in Uttar Pradesh.

MATERIAL AND METHODS

In order to secure the data necessary for the present studied on plankton, regular weekly collections were made with the help of a half metre plankton net. The samples were taken in the morning and one standard haul was made in all operations, each haul being a boat-run for a fixed distance, in the middle of the water bodies under examination. After washing out the catch from the bucket and the net, it was brought to the laboratory in wide mouth collection bottles. A general survey of the samples was done under the binocular microscope for the preliminary identification of the organisms and later it was fixed in 5% formalin. The total volume of the plankton was determined by the standard displacement method, as previously done by Eddy (1927).

In order to study the general characteristics of the plankton, systematic records were maintained of both plant and animal forms occurring in the plankton. Detailed qualitative observations regarding the distribution and fluctuations of zooplankton and phytoplankton components have been made separately, as detailed in the following pages.

QUALITATIVE COMPOSITION OF PLANKTON

Zooplankton

The collections show a distinct change in the composition of the zooplankton during the course of the year. These fluctuations in zooplankton during the year are given monthwise below separately, for LaMartiniere and Kathauta respectively :

LaMartiniere Lake :

July—In this month the total quantity of zooplankton was poor. The crustaceans present in the collections were chiefly copepods represented by *Diaptomus contortus*, *Cyclops leuckarti* and *Mesocyclops obsoletus* in various stages of development. Among cladocera some *Daphnia* were noticed occasionally. Rotifers were also common, the chief forms being *Rattulus*, *Brachionus falcatus*, and *Polyarthra*.

August—So far as the plankton is concerned the general condition was very much similar to that of the previous month. In copepods stray examples of *Mesocyclops obsoletus* were observed but *Diaptomus contortus* and *Cyclops leuckarti* were present in large numbers. Cladocera were rare. Among the rotifers nearly the same forms were seen which appeared in the last month.

September—In this month copepods increased considerably the chief forms identified were *Diaptomus contortus* and *Cyclops leuckarti*. *Diaptomus viduus* also appeared for the first time, but was very rare. *Mesocyclops obsoletus* seemed to have disappeared. Cladocera featured remarkably and were represented by *Daphnia longispina* and *Ceriodaphnia cornuta*. Crustacean larvae were very common. Among rotifers *Conochilus volvox*, and *Brachionus falcatus* were seen. Nymphs of mayfly, dragonfly also made their appearance.

October—Of the copepods, *Diaptomus viduus* was still comparatively rare, but *Diaptomus contortus* was very common. In *Cyclops leuckarti*, if judged by the number of ova carried by each female, it was the peak reproductive period for this species. Among the cladocera, along with the two species i.e. *Daphnia longispina* and *Ceriodaphnia cornuta*, two more species viz. *Moina dubia* and *Diaphanosoma excisum* were present. The size of the eyes of *Moina dubia* was much larger than that of the normal individuals. *Daphnia* had eggs in their brood sacs. Rotifers were represented by the same number of species as described in the previous month. Statoblasts of two species of Bryozoa namely *Plumatella punctata* and *Plumateella fruticosa* were noticed. In insect larvae chiefly those of some dipterus insects and nymphs of dragonfly of the genus *Brachythemis* and *Ictinus* along with some of mayfly were common.

November—Again all the four species of copepods were well represented but *Diaptomus contortus* and *Cyclops leuckarti* were particularly numerous. Among cladocera which experienced an increase in their population, examples of *Daphnia longispina*, *Ceriodaphnia cornuta*, and *Diaphanosoma excisum* were common. Stray examples of *Moina dubia* were also seen. Rotifers were represented by two species *Rattulus* and *Brachionus falcatus* only, as *Conochilus volvox* did not appear in the samples. Insect nymphs were reduced in numbers but all the forms noted previously were represented.

December—The plankton condition remained the same as in the previous month. Among copepods only three species, viz. *Diaptomus contortus*, *Diaptomus viduus* and *Cyclops leuckarti* appear to have been absent in this month. The same species of cladocera were present as noticed in November, but the number of *Moina dubia* increased as compared with other species. *Bosmina* species were also obtained during this month. Cladocera were most abundant in this month and Crustacean larvae also constituted a good proportion. Rotifers and insect nymphs were represented by the same species as noticed in November.

January—In this month the population of Diaptomus was far more than that of *Cyclops*, although the same three species were present. Cladocera were represented

PLATE I

JULY

AUGUST

SEPTEMBER

Photographs of plankton samples from LaMartiniere.

PLATE II

OCTOBER

NOVEMBER

DECEMBER

Photographs of plankton samples from LaMartiniere.

PLATE III

JANUARY

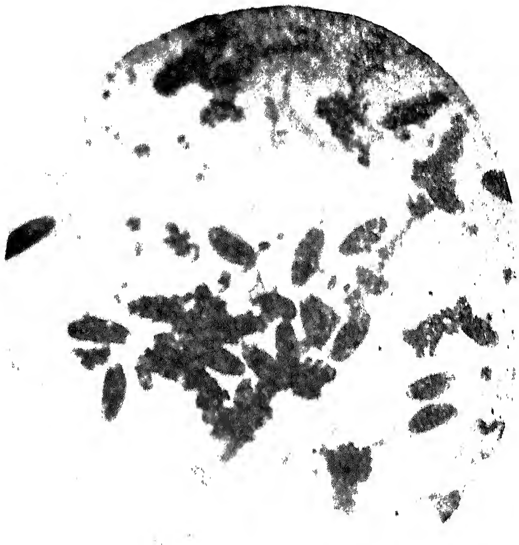
FEBRUARY

MARCH

Photographs of plankton samples from LaMartiniere.

PLATE IV

APRIL



MAY

JUNE

Photographs of plankton samples from LaMartiniere.

by *Ceriodaphnia cornuta*, *Diaphanosoma excisum*, *Bosmina* species and *Maina dubia*. Crustacean larvae and rotifers were seen occasionally. Insect larvae again increased in population, the main components being nymphs of mayflys, damselflys and dragonflys.

February—The zooplankton showed a poor catch in this month. Among copepods, *Diaptomus contortus* and *Cyclops leuckarti* were common while *Diaptomus viduus* was rare. Cladocera were featured mainly by the presence of *Ceriodaphnia cornuta* and *Moina dubia*, while the others were seen occasionally. Crustacean larvae, rotifers and statoblasts of Bryozoa, through observed in some samples of this month, had a very poor population. Nymphs of mayflys and damselflys were common.

March—The composition of plankton was somewhat similar to that observed in the previous month. Only two species of copepods, *Diaptomus contortus* and *Cyclops leuckarti* were noticed. Cladocera were represented by the same species as seen in February. Rotifers and a few statoblasts were observed occasionally. Some ostracods appeared in the collections but their number was very poor. Insect larvae and nymphs present were chiefly those of mayflys and dragonflys only.

April—The copepod population increased to a great extent and all the four species were present. *Diaptomus* were seen in their various developmental stages. The single species of *Cyclops leuckarti* was common and was breeding. Of the species of cladocera, examples of *Moina dubia* and *Ceriodaphnia cornuta* were common, while the other two species were rare. Crustacean larvae showed an increase in their number. Examples of ostracods e.g. *Cypris* and *Eucypris* were noted in samples. Rotifers also increased in number and the chief components seen were *Euchlanis dilatata*, *Brachionus falcatus*, *Rattulus* species, and some forms of *Asplanchna brightwelli*. Insect nymphs were almost the same as in March.

May—In this month only three species of copepods were seen in large numbers. *Diaptomus contortus* and *Diaptomus viduus* were very common, while *Cyclops leuckarti*, though not numerous were by no means rare. *Mesocyclops obsoletus* appeared to have disappeared totally. This was the breeding period for *Diaptomus*. Among cladocera, examples of *Diaphanosoma excisum* and *Cariodaphnia cornuta* were rare, and few examples of *Moina dubia* were observed. Crustacean larvae featured in the samples abundantly, and among rotifers, *Brachionus falcatus* and *Rattulus* species were the prominant forms present while *Copeus caudatus* appeared for the first time in collections and *Asplanchna brightwelli* were not seen. Ostracods did not show any special change in their species from that noted in the previous month. Occasionally some statoblasts of *Plumatella fruticosa* were seen.

June—The general conditions of the plankton remained the same as in the month of May. All the three species of copepods were represented. *Cyclops leuckarti* and *Diaptomus contortus* were breeding at this time. Among cladocera, *Moina dubia* and *Ceriodaphnia cornuta* were seen casually while *Diaphanosoma excisum* and *Daphnia longispina* seem to have been absent. Rotifers became very conspicuous by the increase in their population as well as some more species were seen, viz. *Philodina* species and *Triathra* species in addition to the forms present in the last month. Ostracods were shared by the same forms present in May.

Kathauta Lake:

August.—In this month zooplankton formed the main components of the collections. The most prominent organisms were copepods and cladocera. Copepods were represented by *Cyclops leuckarti*, *Diapcomus doriai* and *Diaptomus contortus*.

Among cladocera, *Daphnia longispina* were numerous, some forms of *Simocephalus elizabethae, Diaphanosona sarsi* and *Moina dubia* were also noticed. Crustacean larvae were present in various stages of development. Rotifers were frequently represented, the chief forms being *Rattulus* species, *Gopeus caudatus* and *Brachionus falcatus*.

September.—Among copepods the prominent components. were almost the same species, viz. *Cyclops leuckarti, Diaptomus doriai* and *Diaptomus contortus*. Some examples of *Cyclops vaticans* were also observed in the collections occasionally, but the species of Diaptomus were far more numerous than the *Cyclops*. Cladocera were represented by the same four examples observed in the month of August, except *Bosmina* species which appeared in the samples for the first time. Crustacean larvae were taken along with the rotifers which did not show any change in their components from the last month. Nymphs of mayfly and dragonfly were also collected in this month, although in very small numbers.

October.—This month brought a marked decline in the total population of the zooplankton. The number of copepods decreased and the forms common were *Cyclops leuckarti, Diaptomus doriai* and *Diaptomus contortus*, while *Cyclops varicans* which appeared in the last month shared very thin population. In cladocera, *Daphnia longispina, Diaphanosma sarsi*, and *Bosmina* species featured chiefly, but *Simocephalus elizabethae* and *Moina dubia* were comparatively rare. Crustacean larvae were represented in various stages of development. Of the three main species of rotifers present, *Rattulus* species and *Gopeus caudatus* were rare while *Brachionus falcatus* was common. The same insect nymphs observed in October were taken in their different developmental stages, but the mayfly nymphs were in larger number than those of dragonfly.

November.—In this month the total population of zooplankton experienced an increase which was because of the increase in the number of copepods. As far as components were concerned there was no well defined change from the previous month. Almost the same common species, viz., *Cyclops lauckarti, Diaptomus doriai, Diaptomus contortus* were present, but *Diaptomus doriai* were found in smaller number as compared to the other two species. The *Diaptomus* were found relatively in larger population than the *Cyclops*. Of cladocera, examples of *Daphnia longispina* and *Bosmina* species featured greatly, the former bearing eggs in the brood sacs. *Diaphanosoma sarsi* and *Moina dubia* shared in small population, while *Simocephalus elizabethae* appeared to have disappeared. Crustacean larvae and insect nymphs were represented as in the previous month. In rotifers *Brachionus falcatus* were common although few examples of *Rattulus* species and *Gopeus caudatus* appeared in some collections.

December.—So far as the total catch of zooplankton was concerned the general condition was very similar to that noticed in the month of November. Among copepods *Diaptomus contortus* were very common and this species was breeding in this month, but *Diaptomus doriai* and *Cyclops leuckarti* were comparatively rare. There appeared some examples of *Diaptomus viduus*. All the forms of cladocera were present. Few examples or damselfly nymphs were taken occasionally. In rotifers, mainly *Brachionus falcatus* and *Rattulus* species were represented.

January—During the month almost all the four species of copepods were present. *Diaptomus contortus* and *Diaptomus viduus* were specially common, moreover some females were carrying eggs in their egg sacs. Among cladocera *Bosmina* species, *Moina dubia* featured greatly, while *Daphnia longispina* and *Diaphanosoma sarsi*, though not much common, were by no means rare. A few examples of *Simosa elezabathae* made their appearance for the first time in the samples, although in very small numbers. Occasionally the population of cladocera showed a well marked

PLATE V

AUGUST

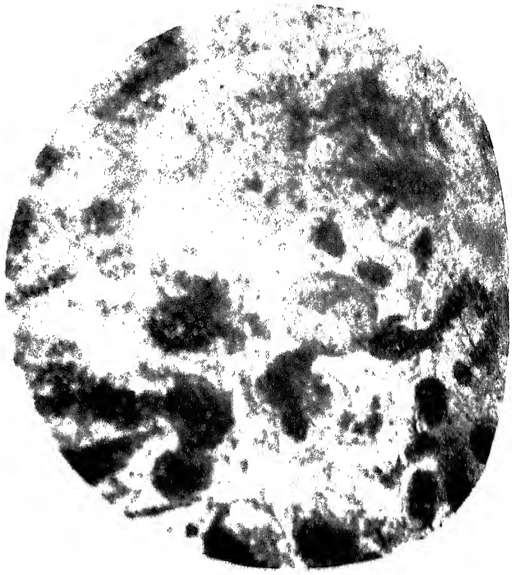
SEPTEMBER

OCTOBER

Photographs of plankton samples from Kathauta

PLATE VI

NOVEMBER



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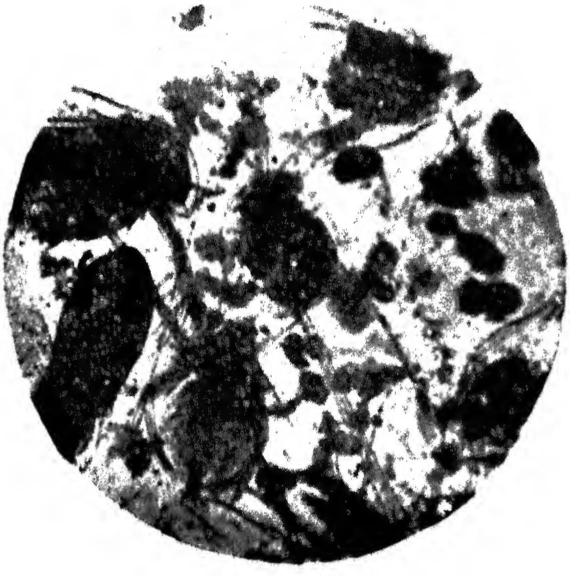
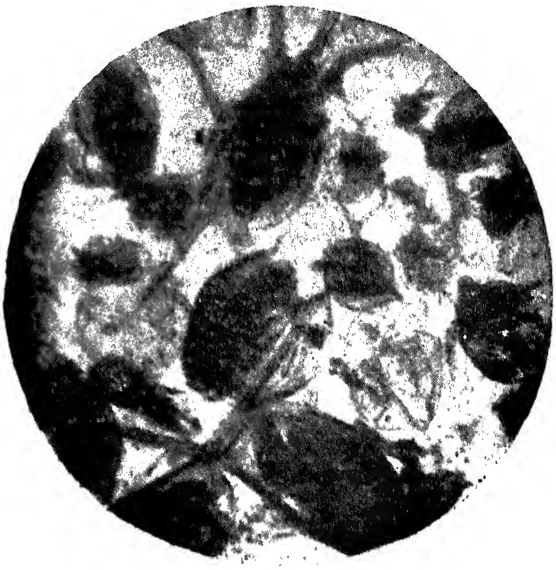


JANUARY

Photographs of plankton samples from Kathauta

PLATE VII

FEBRUARY



MARCH

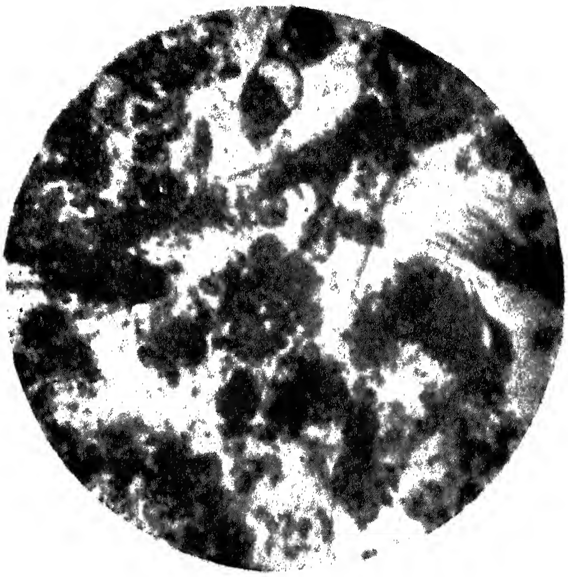
APRIL

Photographs of plankton samples from Kathauta

PLATE VIII

MAY

JUNE



JULY

Photographs of plankton samples from Kathauta

increase. Crustacean larvae were present while there was no change in the components of the insect nymphs. Of the species of rotifers *Brachionus falcatus* was comparatively common.

February—By the end of this month only two species of copepods, viz., *Diaptomus contortus* and *Diaptomus viduus* were represented chiefly, while *Cyolops leuckarti* and *Diaptomus doriai* were rare. On the whole the population of copepods decreased to a great extent but cladocera featured prominently during this month. All the four species, *Bosmina* sp., *Daphnia longispina*, *Moina dubia* and *Diaphanosoma sarsi* were taken in the samples. One sample on the 18th February consisted almost entirely of examples of *Bosmina* sp., and only a few forms of *Daphnia longispina*. Crustacean larvae and the same insect nymphs noted in January were present. Rotifers did not show any change in their components.

March—Of the two species of *Diaptomus*, *Diaptomus contortus* were more common, while *Diaptomus doriai* was not represented in the samples. But a few forms of *Cyclops leuckarti* were present Cladocera experienced a great increase in their population. Almost all the four species were present, in large numbers. But a few examples of *Ceriodaphnia regaudi* and *Simosa elezebathae* were also found during this month. Crustacean larvae in their various stages of development were observed in the samples. Only a few forms of mayfly nymphs were noticed. Among rotifers examples of *Brachionus falcatus* and *Copeus caudatus* were represented. Some examples of water mites namely *Neumaniavolzi indica* and *Eylais degenerata asiatica* appeared for the first time in this month.

April—In this month *Diaptomus contortus* and *Diaptomus viduus* were far more numerous than the *Cyclops leuckarti*. Among cladocera, *Bosmina* sp., *Daphnia longispina*, *Moina dubia* and *Ceriodaphnia regaudi* were common. Only stray examples of *Simosa elezabethae* and *Diaphanosoma sarsi* were seen. Crustacean larvae, some mayfly and dragonfly nymphs were obtained in the samples of this month. The chief characteristic feature of the plankton was the great increase in the number of both examples and the species of the rotifers, the main forms were *Brachionus falcatus*, *Copeus caudatus*, *Rattulus* sp., *Triarthra* sp., and *Euchlanis dilatata*. Some examples of watermites, viz. *Eylais degenerata asiatica* and *Neumania volzi indica* were also obtained in the collection.

May—The population of capepods received a setback during this month and the chief components were *Diaptomus contortus* along with some examples of *Diaptomus viduu*. *Cyclops leuckarti* was rare. Of the species of cladocera, *Bosmina* sp. and *Ceriodaphnia* regaudi were particularly abundant and the rest two species, *Moina dubia* and *Daphnia longispina* were very rare. Crustacean larvae increased in their number but insect nymphs were scanty. Rotifers were conspicuous and one species, of *Brachionus* was prominent, whereas examples of other three forms present in the last month were not so common. Watermites were not observed in the collections of this month.

June—Copepods were represented by the examples of *Diaptomus contortus* and *Cyclops leuckarti* which were breeding. *Diaptomus viduus* were comparatively rare. Among cladocera, *Bosmina* sp. *Ceriodaphnia* regaudi were plenty, while *Diaphnosoma longispina* and *Moina dubia* appeared in very limited numbers. Crustacean larvae were common but insect nymphs were taken occasionally. Rotifers were mainly represented by *Rattulus* sp. and *Brachionus falcatus* and other two forms, *Triarthra* sp. and *Copeus caudatus*.

July—This month revealed no marked change in the components of copepods. Cladocera were prominent and consisted chiefly of *Bosmina* sp. and *Ceriodaphnia regaudi*, While *Moina dubia* and *Daphnia longispina* were rare. Since Crustacean

larvae were present, but the insect nymphs were conspicuous by their absence during this month. The examples of rotifers declined considerably and consisted mainly of one species of *Brachionus falcatus*.

Phytoplankton

LaMartiniere lake :

The phytoplankton was chiefly represented by Chlorophyceae (green algae) including some desmidiacea (desmids, myxophyceae, blue green algae), and Bacillariaceae (diatoms), Some zoospores of various forms were also seen in the collections. The green algae were the most common components. The common genera present were *Volvox, Spirogyra, Pandorina, Scenedemus, Hydrodictyon, Chlorella*, and *Selenastrum*. Desmids were not represented richly in the samples, the two common genra encountered being *Closterium* and *Cosmarium*. The important blue green algae noticed were species of *Gloeotrichia*, and *Anabaena*. And the most common diatoms present were *Fragillaria, Melosira, Synedra, Frustulia, Tabellaria, Navicula*, and *Asterionella*.

Among the phytoplankton of LaMartiniere *Volvox* and *Gleotrichia* accompanied with *Spirogyra* were the most interesting and abundant groups as they developed two water blooms, the first during the monsoon and the other in the late winter months respectively. In the number of genera the list of phytoplankton was headed by the green algae with nine genra. The diatoms were second with five forms while the blue green was the third with three genera only. Some other species of algae had few occasional representatives which were not so universal in occurrence and therefore they have been omitted.

The enormous production of one or more species of algae at one particular time is common in the tropical waters and is called '*water bloom*'. This has received very little attention by the biologists in India. The growth of the algae is often of a single species of a combination of many which develop the bloom. The first water bloom was observed during the months of July and August. The most abundant form which caused the bloom were species of *Volvox*. The water was greenish in colour during that period. The samples contained various developmental and life history stages of *Volvox* along with a few diatoms and *Pandorina*. A second water bloom was noticed during the month of February and the most predominant form which was responsible for the bloom was *Gloeotrichia*. This was also accompanied with the abundance of *Spirogyra* and some diatoms. From the regular analyses of plankton, the nature of the bloom, their duration, attainments of peaks and association with other algae have been found out, and is furnished in the table.

The nature of water blooms and their duration

LAMARTINIERE LAKE

Chief algae forming the bloms	Total duration (days)	Comm-enced on date.	Nature of the Blooms: Peak attained: On date	In days	Peak declined: On date	In days	Water colour	Other algae present	Zoo-plankton
1. *Volvox*	about 33	18-7-54	27-7-54	9	20-8-54	24	green	Nil	Poor
2. *Gloeotrichia*	about 40	27-1-54	6-5-55	10	26-2-55	30	Olive green	*Spirogyra*	Poor

The water blooms appear and disappear or markedly decline in a relatively very short duration. But during the first water bloom by *Volvox*, this period ranged for about 33 days while in the second one in the case of *Gloeotrichia* it further extended to about 40 days. Of the two blooms the later one caused by the *Gloeotrichia* was the densest, moreover its duration was also somewhat longer than that of the first one caused by the Volvox.

Kathauta Lake :

The blue green algae (Myxophyceae) constituted an important component of the phytoplankton. The most common genus present was *Microcystis*, the colonies of which were clathrate or irregular shaped, composed of numerous spherical densely aggregated cells of about 3-4μ. in diameter. This alga gave a characteristic dull green colour to the water. Another plant mass, expanding as a slimy surface layer and whose filaments are unbranched was *Oscillatoria* which were represented in very small number occasionally. Other important components of the plankton belonging to this group were species of *Gloeotrichia* and *Anabaena*. The former forming a free mass floating as bullate, hollow, soft, jelly like, indefinite mucous masses of varying dimensions. The filaments were loosely aggregated, and the trichomes were about 7-10μ in diameter. *Anabaena* appeared as a frothy gelatinous, floating blue green mass.

The green algae (Chlorophyceae) consisted chiefly of *Volvox* with several daughter and grand-daughter colonies inside, and *Spirogyra*, having simple unbranched filaments, composed of cylindrical cells. Other common forms were *Pandorina Eudorina* and *Selenastrum*. Some unicellular green plant masses known as desmids were occasionally presented by *Perium*, *Closterium*, and *Cosmarium*. The diatoms were represented by *Tabellaria*, *Synedra*, *Fragillaria*, *Eunotia*, *Rhopalodia*, *Navicula* and *Cymnella*.

DISCUSSION

Variation in the Number of Species.

Zooplankton :

In the present investigations, 4 species of copepods, and their nauplii, 5 cladocera, 2 ostracods, 9 rotifera and statoblasts of 2 species of Bryozoa have been found in the samples of LaMartiniere lake. On the other hand there were observed 5 species of copepods and their nauplii, 7 cladocera, 6 rotifers and 2 watermites in the plankton collections of lake Kathauta. Three forms of insect larvae were also collected from these water bodies. Comparing these with the records obtained earlier in India, it can be seen that Sewell (1934) reported 10 species of rotifers, 15 cladocera, 10 copepods, 1 ostracod and 3 polyxoa from a tank in Bengal. Chacko and Krishnamurthy (1954) described some copepods and cladocera constituting the zooplankton of some ponds in South India. And Alikunhi *et al* (1955) found 11 rotifers, 2 copepods, 3 cladocera and occasionally some ostracods as important components of the plankton in some nursery ponds in Orissa.

In comparison to these Indian figures, Boyer and Rajkov (1929) counted about 80 rotifers, 22 copepods, and 59 phyllopods in lakes near Ledrice. Kraatz (1931) listed 4 rotifers, nauplius, Cyclops and 2 cladocera while making quantitative net plankton survey near Akron, Ohio. Harda (1933) recorded 1 nematode, 9 rotatoria, 7 cladocera, 10 copepods, 1 ostracod and 1 diptera in a Formosan lake. Scheffer and

Robinson (1939) counted about 35 zooplankton species in washington lake. Damann (1935) maintained plankton records for 17 years in lake Michigan and observed about 223 different organisms during that period of which 67 rotifera, and 37 crustacea were important as fish food. Pennak (1949) discovered 25 species of rotifers, 2 copepods and 5 cladocera in Colorado reservoir lakes. Moore (1950) showed the scarcity of zooplankton in lake Providence in which rotifers were predominant group. Jolly (1952) described an Australian lake which possessed a rich zooplankton chiefly species of entomostracan crustacea. Pearcy (1953) accounted for only 4 species of rotifers and crustacea in Clear lake, Iowa, while Pennak (1955) noted about 26 plankton species of rotifers in Colorado mountain lakes.

It is therefore clear that each water body has its own components of the organisms which represent a variable composition, and each genus displays its own rules in a particular stretch of water. It appears that in Indian fresh water bodies the number of species is comparatively low as compared to other countries, but the number of the individuals is in no case less and may be more than in colder water bodies.

Phytoplankton :

In LaMariniere about 17 phytoplankton components have been recorded by me. While nearly 15 forms were observed in the plankton samples of Kathauta. Ganapati (1943) found that the phytoplankton was represented only by 3 blue green algae while Alikunhi *et al* (1955) accounted for about 34 forms from the phytoplankton of the nursery ponds in Orissa.

Comparing these with the observations of other countries, it can be seen that Ueno (1934) found only diatoms with 20 species as the chief representatives of the phytoplankton in lakes of Etorofer. Buren (1938) noticed 5 blue-green, 5 flagellates, 4 peridinium, 7 diatoms and 6 green algae species during his four years plankton studies in Washington lake. Scheffer and Robinson (1939) recorded about 72 species of phytoplankton from the same lake Washington. It is concluded from the present studies that the water bodies under consideration are rich in phytoplankton components as compared to those of South India. And there are more genera as compared with the number of species in the plankton algae.

Distribution of Species

Zooplankton :

The most common zooplankton components recorded from LaMartiniere were species of *Diaptomous*, *Cyclops* and *Mesocyclops*, among Copepods, the Cladocera were represented by *Daphnia*, *Ceriodaphnia*, *Moina*, *Diaphnosoma* and *Bosmina*, ostracods by *Eucypris*, and *Stenocypris* and the rotifers by *Copeus*, *Asplanchana*; *Rattulus*, *Brachionus*, *Philodina*, *Triarthra*, *Euchlanis*, *Polyarthra* and *Conochilus*, in the collections. Insect nymphs mainly of mayfly, dragonfly and damselfly featured the samples. Occasionally some statoblasts were also noticed. While in Kathauta almost similar forms excepting of Copepods *Mesocyclops* were observed. In cladocera species of *Simocephalus* were present in addition to the forms described in the LaMartiniere lake. The most important thing to note was the negligible catch of ostracods in this lake. Among rotifers, all the forms present in LaMartiniere were obtained excepting *Philodina*, *Polyarthra* and *conochulus*. Stray forms of watermites *Neumania* and *Eylais* were also seen in the collections of Kathauta lake.

In Calcutta, Sewell, (1934) reported the presence of *Ceriodaphnia*, *Diaphanosoma*, *Moina*, *Leydigia*, *Pseudalona*, *Alona*, *Leucryptus*, *Simocephalus*, *Dunhevedia*, *Scapholebris*, *Chydorus*, *Macrothrix* in cladocera. Among copepods, *Diaptomus contortus*, *Meyesocyclops leuckarti*, *Mesocyclops vericans*, *Diaptomus cinctus*, *Paracyclops fimbriatus*, *Eucyclops prasunis* and *Eucyclops phaleratus* were common. And among rotifers *Copeus caudatus*, *Euchlanis dilatata*, *Conochilus volvox*, *Asplanchna brightwelli*, *Triarthra longisetosa*, and *Brachionus falcatus* were common in Museum tank at Calcutta. Ganapati (1943) found that the bulk of zooplankton consisted of copepods and cladocera only in a pond in South India. Chacko and Krishnamurthy (1954) also noted only copepods and cladocera constituting the zooplankton of some ponds. While Alikunhi *et al* (1955) reported the important zooplankton components as the rotifers, viz., *Brachionus*, *Keratella*, *Noleus*, *Lecane*, *Salpina*, *Asplanchna*, *Pedalia*, *Polyarthra*, *Filina*, *Tetramastin* and *Conchilus*, the copepods as *Diaptomus* and *Cyclops*, the cladocera as *Moina*, *Diaphanosoma* and *Geriodaphina*. Occasionally some Ostracods were also seen in the nursery ponds in Orissa.

Comparing the composition and distribution of these planktonic forms, with those reported from various countries an important difference is marked. Rylov (1926), reported zooplankton as an abundant part of plankton and the rotatoria being the predominent group. Tressler and Bernard (1931) observed that *Cyclops* was the most abundant of the crustacean plankton. Berg (1930) found in Lake Issyk-kul (*Turkestan*) that the plankton is poor in number of species, and the cladocera were totally absent. Antona (1933) summarised his results from his observation in Lake Nemi which were characterized by the prevalence of *Daphnia* and *Leptodora*. But after a further lowering of level of water *Daphnia* disappeared and *Diaphanosoma* and rotifers dominated the plankton. Thus there is a great qualitative distinction in the composition of plankton in various water bodies. Moreover there appears considerable difference in the composition of the plankton of the water bodies under consideration to those of European and American lakes. Besides, several groups of plankton organism from these waters show less cosmopolitanism. However, it has been noted that if the differences of species is disregarded and only genera are considered, then the zooplankton of LaMartinere resembles more closely that of Kathauta lake in a qualitative sense, but differs largely with the observations of Chacko and Krishnamurthy (1954) and Alikunhi *et al* (1955). It can also be noticed that the bulk of zooplankton consited chiefly of copepods and cladocera in both the water bodies.

Phytoplankton :

The Chlorophyceae were well represented in species and individuals but the dominant form counted in LaMartiniere were only two leading genera in order of their importance, *viz.* *Volvox* and *Spirogyra*. *Volvox* featured greatly in July and August which resulted in the first plankton peak. But there was a sharp fall in its population in October and finally disappeared. Fragments of *Spirogyra* were found occasionally upto the month of December, but it increased during the months of January and February till it reached its maximum in March which was followed by a marked decline in subsequent months. Although *Volvox* was represented throughout the year in Kathauta their population was very thin as compared to LaMartiniere. This was common during April and May. *Spirogyra* was taken throughout the year in Kathauta, except in the months of July and August. In addition to these about eight more algae, *viz.* *Chlorella*, *Hydrodictyon*, *Scenedesmus*, *Pandorina*, *Selenastrum*, *Closterium* and *Cosmarium* were noticed in LaMartiniere. Of these only *Pandorina*, *Selenastrum*, *Closterium* and *Cosmarium* were common in the samples of

Kathauta, while others were very scanty. But the rarity of these was compensated by the addition of *Eudorina*, and *Goniam*. While in some other occasional reports, *viz*, Chacko and Krishnamurthy (1954) described *Pediastrum*, *Scendesmus* and *Ankistrodesmus* from fish ponds of peninsular India. And Alikunhi *et al* (1955) reported *Volvox*, *Eudorina*, *Chlamydomonas*, *Westella*, *Coelastrum*, *Pediastrum*, *Scenedesmus*, *Crucigaenia*, *Kirchneriella*, *Goniam*, *Actinastrum*, *Dictyosphaerium*, *Ophiocytium* and *Tetraedron* from some nursery ponds at Cuttack. As such it is seen from the present observations that there are less number of species in these waters as compared to the ponds and tanks referred to above by others.

Similar seasonal abundance of the green algae has also been found by other workers. Steuer (1910) reported that this algae reached the maximum abundance in summers in most lakes of Leipzig. West and West (1912) noted that greens were most abundant in autumn in lakes of England and Scotland and similar results have been obtained by Wright (1955) Western Lake Erie. Smith (1924) stated that large growths of algae usually appear in late spring or early summer while Tressler and Bernard (1931) noticed in Lake Wingra spring and fall maxima. On the other hand I have observed that green algae as a group increased rapidly during July and August and showed a decline in following months, but became common again during winter in the La Mratiniere. However this group did not reveal any marked abundance in Kathauta, although it was represented throughout the year.

The common diatoms present in both water bodies were *Synedra*, *Fragillaria*, *Navicula* and *Tabellaria* while other forms present only in La Martiniere were *Frustulia*, *Asterionella*, *Melosira*, And in Kathauta *Eunotia*, *Rhopalodia*, and *Cymbella* were seen in addition to the forms refered above. It has been further noted that diatoms were represented, although in very small numbers, throughout the year in La Martiniere but they increased in January and February, after which their population decreased considerably in the following months. While in Kathauta they were common from August to February and later shared a very small population. While Chacko and Krishnamurthy (1954) noticed in a South Indian pond that *Melosira*, *Nitzochia* and *Synedra* were predominant during November to March. And Alikunhi *et al* (1955) found that *Navicula* and *Melosira* were most common in the nursery ponds in Orissa, though in a majority of collections these were relatively few in number. Melosira, however, was dominant in the month of August.

The frequent blue green algae (myxophyceae) seen in La Martiniere were *Anabaena*, *Gloeotrichia* and *Oscillatoria* and these were also, almost equally common in Kathauta. In addition to these *Microcystis* was particularly prominent in this lake. In La Martiniere *Gloeotrichia* formed an important constituent from January to March and was responsible for the second plankton peak in February. And thus the statement made by Welch (1948) that the blue green algae (myxophyceae) and green algae (chlorophyceae) virtually disappeared during winter, does not hold true for north Indian freshwaters. In Kathauta *Anabaena* was abundant in the months of September to January and *Microcystis* during months of May to July.

Further we may conclude that myxophyceae as a group was dominant during winter in La Martiniere, while in Kathauta it was most prominent in summer. But the phytoplankton components differed in quantity and quality to a large extent. Chacko and Krishnamurthy (1954) observed that a pond had an almost permanent bloom of *Microcystis* in 1947-48. And Alikunhi *et al* (1955) reported that *Microcystis* was found a close second in being the commonest algae in the nursery pond at Cuttack. Their observations that its maximum production is reached during hot weather, corresponds well with the present investigations in case of *Mycrocystis*. As

such it is apparent that different groups of phytoplankton affected are by the different sets of environmental conditions, which are responsible for the maxima and minima of any particular group of algae at a particular period in a given stretch of water.

Waterblooms :

The production of 'waterblooms' is a very common feature in freshwaters irrespective of latitude or altitude. But it is a surprising fact that the word 'waterbloom' does not appear in the Oxford English Dictionary although it is a term which describes a natural phenomenon of quite frequent and widespread occurrence. The blooming may generally be due to a single species or a combination of a few more as seen in the present study. This may also occur in combination with many other species. Singh (1955) reported some species belonging to myxophyceae specially of *Microcystis aeruginosa, Microcystis flosaquae, Anabaena circularis, Raphidropis indica, Anabaena aphanizamenoides, Wollea bharadwajea* and species of *Oscillatoria* and *Spirulina* as the chief components in various water blooms during the year. Chacko and Krishnamurthy (1954) reported blooms of one or more species of algae and stated further that permanent blooms of *Microcystis* species is a special feature of south Indian temple ponds. This is not true of any lake considered in the present investigation. However, in the present observations it has been seen that *Volvox* and *Gloeotrichia* were largely responsible for water blooms during the months July-August and February respectively. The duration of the first one ranged upto 33 days while the second of *Gloeotrichia* took about 40 days. On the other hand the water blooms recorded by Alikunhi *et al* (1955) in some nursery ponds were relatively of a shorter period. In the case of *Eudorina* this period varied from 10 to 24 days only.

In other countries, Hasler (1947) noted the sudden and sporadic outburst of various phytoplankton species specially the myxophyceae which often comprise the nuisance blooms of some lakes. Pennak (1949) also reported the unusual existence of algae bloom nuisance. He noted that the bloom began as early as April and persisted until autumn, in which the alga originated as an extremely loose mat of intermingled microscopic gelatinous colonies. Biswas and Calde (1955) reported from Calcutta that during the hot weather the alga (*Microcystis*) reaches its climax and is sometimes mixed with a free floating, blue green plankton alga (*Anabaena flosaque*) that form the water blooms. They have further established that *Pandorina*, often associated with *Euglena* turns the water surface green and forms another water bloom.

It is therefore concluded from the abovementioned observations, that the size and the depth of the water body do not affect much the qualitative development of the plankton algae. But the phytoplankton does show a wide range of differentiation from those reported in larger lakes of foreign countries. This is mainly due to environmental differences. It is further proved that a special feature of the plankton flora in Indian water bodies is the existence of only a few species which are most common, but that these are represented by a very large number of individuals. Moreover, there is mostly paucity of desmids and dominance of myxophyceae in Indian waters. And as such the plankton flora can be named as the *Baltic type* although this is freshwater in India.

Finally, it may be put on record, without fear of contradiction, that the water-blooms observed by the authors, are a very characteristic feature of all North Indian lentic water-bodies, and that no particular bloom is continuous throughout the year,

LIST OF ZOOPLANKTON COMPONENTS

I. **Crustacea :**

Copepods

Cyclops leuckarti

Diaptomus doriai

Diaptomus contortus

Cyclops varicans

Diaptomus viduus

Mesocylops sp.

II. **Cladocera :**

Daphnia longispina

Simocephalus elizabethae

Diaphanosoma sarsi

Moina dubia

Bosmina sp.

Simosa elizabethae

Ceriodaphinia regaudi

III. **Ostracoda :**

Eucypris sp.

Stenocypris sp.

IV. **Rotifera**

Asplanchna brightwelli,

Rattulus sp.

Gopeus caudatus

Brachionus falcatus

Paludina sp.

Triarthra sp.

Conochilus sp.

Euchlanis dilatata

Polyarthra sp.

V. **Insect larvae :**

Mayfly larvae

Dragon fly ,,

Damselfly ,,

Watermites

Neumania volzi indica

Eulais degenerata asiatica

LIST OF THE PHYTOPLANKTON COMPONENTS

I. **Green Algae :**

Chlorella

Hydrodictyon

Scenedesmus

Spirogyra

Volvox

Pandorina

Solenastrum

Closterium

Cosmarium

Gonium

II. **Diatoms :**

Fragillaria

Syn dra

Frustullia

Navicula

Rhopalodia

Asterionella

Rhizosolenia

Tabellaria

Mel osira

Eunotia

Rhopalodia

Cymbella

III. **Blue Green Algae :**

Anabaena

Oscillatoria

Gloeotrichia

SUMMARY

In order to study the general characteristics of plankton, systematic collections have been made for a period of two complete years. Detailed qualitative observations regarding the seasonal distribution and fluctuations of the plankters have been recorded, as detailed in the paper. The number of individual species of both phyto-and zooplankton have been taken into consideration and their appearance and pulses have also been observed in freshwaters of North India.

While comparing the present observations with those made for other water bodies, it has been seen that each stretch of water had its own component of organisms, which shows a variable composition; while each genus displays its own peak. It is also interesting to note in these water bodies that zooplankton, at least, is poor in species although not in individuals, compared with that in other parts of the world, particularly the colder ones.

It is evident from the present studies that these water bodies are remarkably richer in phytoplankton forms as compared to those of South or peninsular India. Moreover, there are more genera present as compared with the number of species in the plankton alage.

After a considerable fall in their catch, phytoplankton components definitely show a cyclic appearance although it might not be the same particular species of alga.

Finally, the components of Indian freshwater plankton and their composition and seasonal fluctuation is totally unlike what is obtained in the seas around India.

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STUDIES ON FRESH WATER PLANKTON PART—IV

THE FISH-FOOD AND THE ROLE OF PLANKTON COMPONENTS*

By

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ABSTRACT

Important and interesting interrelations have been found to exist between the gut contents of certain fishes and the abundance of particular species of plankton in fresh waters of North India. No such studies have been attempted for Indian freshwaters until now. The plankton catches have been compared with the gut-contents of the fishes taken at the same time and these two show a pertinent and reasonable correlation. The majority of plankton feeding fishes have been found to be Omnivorous. The percentage composition of food of certain plankton feeding fishes are given in the paper.

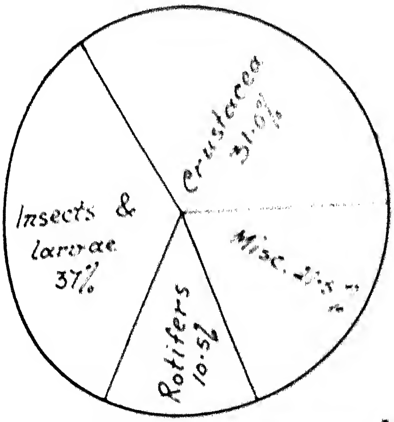
INTRODUCTION

The importance of plankton for the existence of life as a whole in a lake or any lentic habitat is very great. This is because of the fact that the formation of organic matter, through the chlorophyll of green plants in sunlight, occurs in the littoral zone through the intermediary of higher vegetation and in the bulk of open water (the pelagic zone) through the intermediary of plankton algae. The role played by plankton as supplier of organic substance, which directly or indirectly serves all the living organisms of the lake (including fishes) as food, is of prime importance for consideration. Moreover, plankton also forms the biological community which after dying and sinking to the bottom form the nature of the bed deposits of the lake.

The most outstanding feature in the aquatic complex is the partial or complete and direct or indirect food dependence of aquatic animals upon the plankton. Particularly some fishes are typical active plankton feeders throughout their life and all others at some stages of the life cycle. Thienemann (1954) pointed out emphatically "Are there fishes in South East Asia which feed exclusively on animal plankton as do some of our species of *Coregonus* ? I do not know." And he felt that this problem requires a detailed study. Studies on the role of plankton as fish food has been carried out by Ichthyologists in various countries. Birge (1945) observes that cladocera are of greater value as food of young fishes and there is a period in the life cycle of almost every fish when it feeds exclusively on entomostraca. Important observations on similar lines have been made by eminent Ichthyologists all over the world.

In India Khan (1934) studied the habits and habitat of fishes and expressed that *Labeo rohita* fry and fingerlings upto the age of nine months feed heavily on crustacea and mosquito larvae. Job (1940) found that *Therapon jarbua* was a surface feeder due to the presence of insect larvae and mosquito adults in the stomach

* The results of the qualitative and the quantitative studies on freshwater plankton are given in other papers as parts. I, II, & III of the series with two plates.



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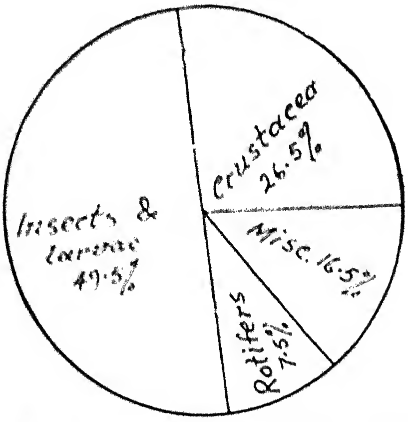

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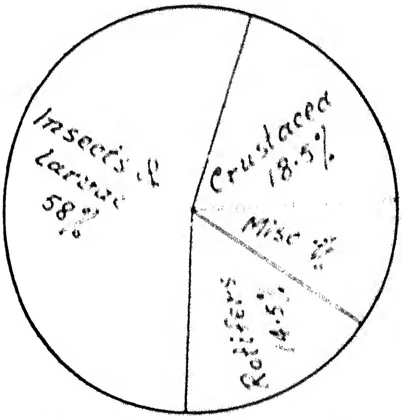
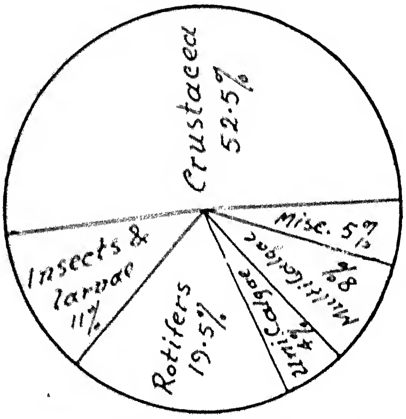
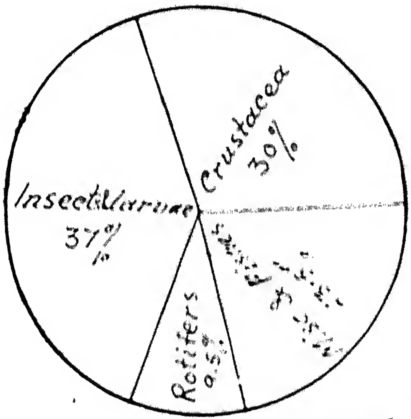


Mystus vittatus



Ambassis nama



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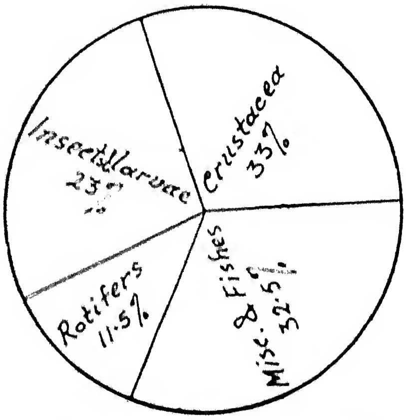
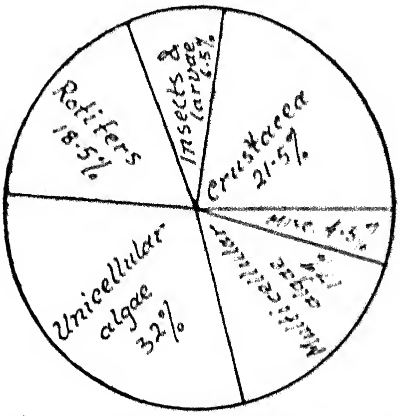


Wallagonia attu



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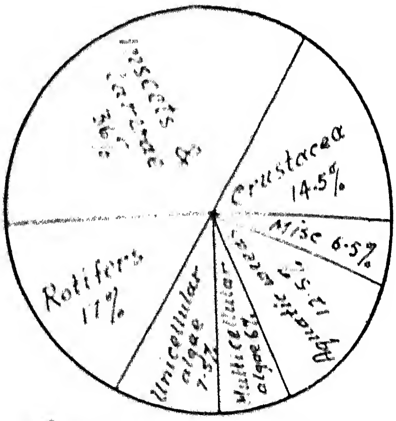
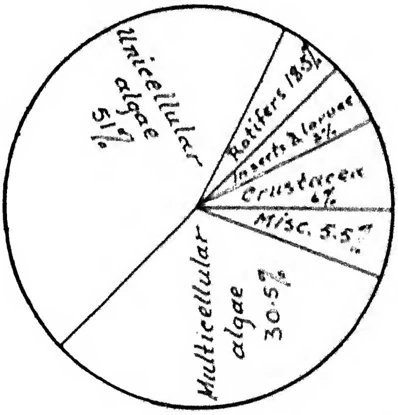
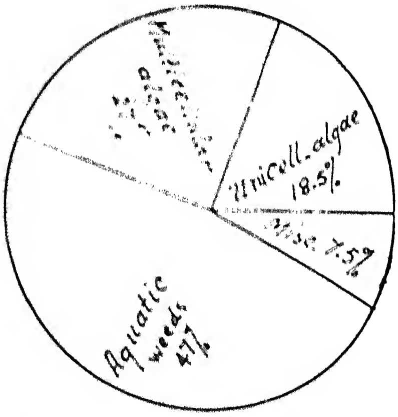


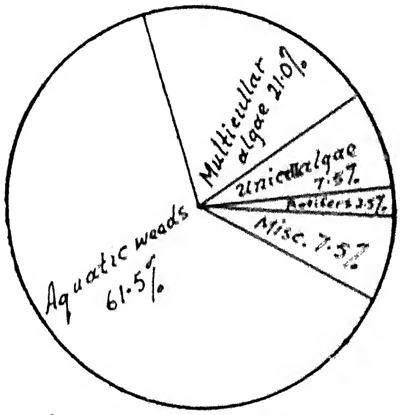
Puntius sophore



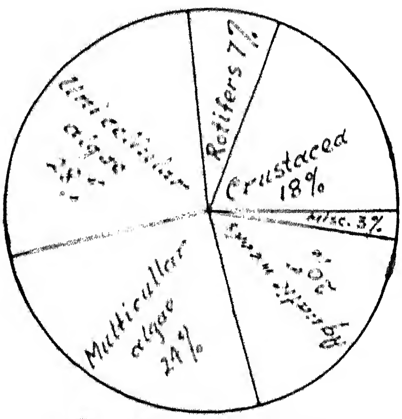
Amblypharyngodon mola



Cirrhina mrigala



Labeo rohita



Catla catla

contents. Hora (1943) observed that micro-phytoplankton serves as food for fry of the carps in earlier stages of growth. Mookerji *et al* (1946) gave a brief account of food of fishes and its percentage composition in the common adult food fishes of Bengal. Das and Moitra (1955, 56a 56b) recorded a relation between the type of food and the feeding habits of certain fishes of U. P. along with quantitative correlation between the different food elements, as well as gut modifications due to type of food. Finally, Das (1957) gave some inter-relations of fish-food and fishes.

In the present contribution, by examining the gut contents of a large number of food fishes from Lucknow, it has been found that the main bulk of the food taken by the fishes consists of plankton algae, rotifers, crustaceans, insect larvae and adult insects.

The plankton-feeders are not sharply marked off into phytoplankton-feeders and zooplankton-feeders. The bulk of these fishes are therefore omnivorous-a feeding type which is probably the most primitive among fishes. It would be no exaggeration to state that without plankton (*i.e* nannoplankton, phytoplankton, obligoplankton, rheoplankton, zooplankton, benthoplankton, limnoplankton and helioplankton) not a single fish in lakes or rivers would be able to thrive (and complete its life-history) for any length of time; and *the entire freshwater fisheries of a country would completely fail if plankton production were to stop.* This complete dependence of freshwater fisheries on plankton cannot be over-stressed, and specially in a country such as India, plankton production programmes should have top priority for fish-seed production in fish-farming or pisciculture projects.

MATERIAL AND METHODS

Fishes were obtained from the regular fish hauls which were made in lentic waters along with the collection of plankton samples at Lucknow. Adult fishes, were measured, weighed and identified in the laboratory. The abdomen of each was then opened and the fishes were fixed in 10% formalin for further observations of the gut contents. When examining the food, the stomach and intestine were carefully removed and opened with the help of fine scissors. The contents were then washed out with water, and collected into a clean petri-dish. All the animal and plant materials were identified and counted under the microscope. Similar standard methods were also used in collection, fixation and observation of the gut contents of the young fishes and fingerlings. A general survey of the plankton components was also made simultaneously. All these observations along with the date, time, locality and the name of the water bodies were recorded regularly.

GUT CONTENT ANALYSIS OF THE ADULT FISHES

While working out the type of food in the fishes mentioned below it has been observed that a majority of them show definite affinities to the various water-levels at which they feed.

The results obtained from a regular analysis of the food material of the fishes e.g. *Catla catla, Labeo rohita, Cirrhina mrigala, Puntius sophore, Notopterus notopterus, Wallagonia attu, Mystus vittatus, Ophicephalus marulius, Ophicephalus striatus, Ambassis nama, Amblypharyngodon mola and Mastacembelus armatus* are presented in a systematised and tabulated form below :

Fishes	Gut contents	Feeding Habits	Remarks
Catla catla ...	Cladocera, copepods, diatoms, desmids and the plankton alegae along with leaves and roots of soft aquatic plants	Surface & column feeder; also plankton	Herbivorous (plankton omnivore)
Labeo rohita ...	Filamentous algae, diatoms, parts of aquatic plants, insect larvae and vegetable debris	Column feeder or mid-feeder also plankton	Herbivorous (plankton omnivore)
Cirrhina mrigala	Decomposed soft parts of aquatic weeds, some copepods, filamentous algae, and Diatoms and mud	Bottom or column feeder	do.
Puntius sophore ...	Tender roots and leaves of aquatic plants, desmids, rotifers, cladocera and copepods with sand	do.	Omnivorous (plankton carnivore)
Notopterus notopterus	Small fishes, fingerlings snails, bryozoa, statoblasts, shrimps fish scales, daphnids and copepods, along with insects and nymphs of dragon flies	Predator & plankton feeder	Carnivorous (plankton carnivore)
Wallagonia attu ...	Smaller fishes, fingerlings, shrimps, acquatic insects, water-mites and Daphnids	Predatory column feeder	Carnivorous
Mystus vittatus ...	Zooplankton : particularly daphnids, copepods, ostracods, shrimps, insects and mosquito larvae; also small fish	Column feeder	Carnivorous (Plankton carnivore)
Ambasis nama ...	Planktonic algae, *viz.* diatoms unicelluar algae and desmids; rotifers, copepods and daphnids; mosquito larvae	Plankton surface feeder	Omnivorous

Fishes	Gut contents	Feeding Habits	Remarks
Trichogaster fesciatus	Both phyto and zoo-plankton organisms; mosquito larvae	Plankton column feeder	Omnivorous
Amblypharyngodon mola	Waterfleas, copepods, rotifers, diatoms, desmids and unicellular algae; mosquito larvae	do.	do.
Ophicephalus marulius	Shrimps, copepods, daphnids; Insects and their larvae, water bugs, water mites; fish fins and fish scales along with delritus and mud.	Predatory bottom feeder	Carnivorous
Ophicephalus stratus	do.	do.	do.
Mastacembelus armatus	Zooplankton crustacea, mayfly, dragonfly nymphs, debris and some unicellular algae	Column feeder	Carnivorous (Plankton carnivore)

GUT CONTENT ANALYSIS OF THE YOUNG FISHES

The gut contents of the young fishes, particularly at the fry and fingerling stages of almost all the fishes, consisted chiefly of: the planktonic organisms, *viz.* Cladocera, copepods, nauplii, insect larvae, rotifers and certain protozoa along with the microscopic algae, *viz.* diatoms, desmids, *Volvox*, *Pandorina*, *Euglena* etc. The composition of a few fish-fry and fingerling gut-contents analysed at Lucknow are given for comparison.

Fishes examined	Fry	Fingerling
Labeo rohita ...	*Ceriodephnia*, *Cyclops*, *Navicula*, *Milosira*, *Pandorina*	*Cyclops*, *Diaptomus*, *Daphnia*, *Bosmina*, *Closterium*, *Cesmarium*, *Chlorella*, *Euglena*, *Volvox* and vegetable debris
Labeo calbasu ...	*Bosmina*, *Moina*, *nauplii*, *rotifers*, *Navicula*, *Euglena*, *Cosmarium* and *Closterium*	*Daphnia*, *Cyclops*, *Simocephalus*, *Chlorella*, *Volvox*, *Closterium*, *Pandorina*, *Frustulia*, *Synedra*, and *Spirogyra* etc.
Catla catla ...	*Daphnia*, *Cyclops*, *Bosmina*, *rotifers*, *Microcystis*, *Volvox*; *Pandorina* and *Spirogyra*	Filamentous algae *Volvox*, soft parts of plants *Bosmina*, *Closterium*, *Cosmarium*, *Navicula*, *Synedra*, *Chlorella*.

Fishes examined	Fry	Fingerling
Cirrhina mrigala	*Moina, Bosmina, Rotifers, Ceriodaphnia, Euglena, Navicula, Cosmarium*	Filamentous algae, *Volvox, Chlorella, Pandorina, Navicula, Synedra, Cosmarium,* and vegetable detritus.
Notopterus notopterus	Insects larvae, particularly dragon fly and mayfly nymphs; *Daphnia, Bosmina,* nauplii, and rotifers, and some planktonic unicellular algae	Aquatic insects, and insects-nymphs. *Daphnia, Daphniosoma, Simocephalus, Bosmina, Diaptomus,* rotifers, along with some desmids and diatoms.
Wallagonia attu	Insect larvae, Daphnia, mayfly and dragonfly nymphs; rotifers, nauplii, and debris with mud.	Aquatic Insects their appendages; larval insects, *Daphnia, Bosmina,* water mites, small fish, scales and fish fins, detritus and mud.

DISCUSSION

There are definite inter-relationships between the different biotic elements of the aquatic ecosystem, *viz.,* phytoplankton, zooplankton and fish. In freshwater also, as in the sea and in the terrestrial environment, the prime association between organisms is the one related to nutrition.

A study of the food of different species of fishes in U. P. has revealed that many of them feed on plankton. It had been observed in the sea, at widely separated locations all over the world, that there is a positive correlation between the density of plankton and the density of the plankton-feeding fish population. Hardy *et al* (1936) found out by means of plankton indicator, that in most instances the greatest number of adult herring were caught in water rich in *Calanus*. Similarly, along the west coast of India, Chidambaram and Menon (1945) found that the landings of plankton-feeding fish were directly proportional to the quantity of plankton produced in the different months. Although no such definite conclusions on fish population could be drawn in the present studies (as this would itself have formed a separate problem by itself) the main plankton feeding food fishes (with main food as plankton) have been sorted out by examination of the gut-contents. It has also been observed that phyto-and zooplankton both serve not only as a direct source of food supply to the plankton-feeding fishes but indirectly to other fishes also.

It has been further established for the fishes, worked out in the present investigation, that those which feed exclusively on plankton are generally Omnivorous, since none of them feed entirely on either zooplankton or phytoplankton in nature. The carnivorous and herbivorous tendencies depend to a large extent upon the existing environmental conditions *i.e.* the availability of the type of food matter, as we have observed pulses of zoo-and phytoplankton components in the gut contents of certain fishes at a particular time. On comparing the plankton records with these maxima, definite correlations have been found to exist between the available food material (plankton) and the food taken by the fish (gut content).

This has been found to be specially so in the fishes *Catla catla*, *Chela bacaila* and *Ambassis nama*, when they fed almost exclusively on *Volvox carteri* which was in flower at that time (Das and Srivastava, 1956).

SUMMARY

In the course of our studies on the ecological conditions and fish-food in North Indian freshwaters, important and interesting interrelations have been found to exist between the gut contents of certain groups of fishes and the abundance of a particular species of plankters. The main role played by the plankton as suppliers of organic substances, which directly or indirectly keeps alive the organisms including fishes of the water body, has been recognised all over the world.

No such studies, however have been attempted for Indian waters. We find that there is partial or complete food dependence of the fishes studied upon the plankton at some stage or the other of their life-cycles. Particularly, some fishes, viz., *Gadusia chapra*, *Labeo sp.*, *Hilsha*, *Eutropichthyes vacha*, *Ambassis nama*. *Chela bacaila*, *Puntius sophore*, *Rasbora daniconious*, *Danio devario* and *Catla catla*, are reporetd in the present pages as such plankton feeders.

The plankton catches have been compared with the gut contents of the fishes taken from the same environment at the same time. These show a pertinent and reasonable correlation. It has been also found that some of the plankton-feeding fishes are either *carnivores* feeding more percentage of zooplankton (*viz.* copepods cladocera, ostracods, insect larvae and rotifers) in the main; or the herbivores, whose food consists of large number of planktoni algae both unicellular, multicellular as well as diatoms, desmids and vegetable detritus). While the *omnivores* take both zooplankton and phytoplankton components with equal facility. These observations also reveal that the majority of plankton feeding fishes are omnivorous plankton feeders.

The young stages of all these fishes feed almost exclusively on plankton, the species ingested depending to a large extent on the plankton-peak species at that time. The discovery of plankton food cycles of particular food fishes is of great importance in both pond culture and pisci-culture projects. The percentage composition of food of certain plankton.feeding fishes are given in the paper.

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ON A NEW TREMATODE, *EUPARADISTOMUM FRANCOLINI* N. SP. (DICROCOELLIDAE) FROM THE GALL BLADDER OF A BLACK PARTRIDGE

By

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[Received on 9th December, 1957]

Two mature specimens of the trematode described herein were collected from the gall bladder of a Black Partridge, *Francolinus francolinus* (Linnaeus) shot by me at the outskirts of Anupshahr (District Bulandshahr, Uttar Pradesh) in the year 1955.

DESCRIPTION

The body of this trematode is aspinose, flat, and broadly ovate with rounded ends. It measures 3·86 — 4·66 mm. in length, and 2·93 — 3·39 mm. in maximum breadth at the equatorial level. The oral sucker is subterminal, and measures 0·635 — 0·713 mm. in length, and 0·668 — 0·88 mm. in breadth. The ventral sucker is larger than the oral sucker measuring 0·77 — 0·99 mm. in length, and 0·89 — 0·99 mm. in maximum breadth. It is situated at about the middle of the body. A prepharynx is absent. The pharynx is 0·2 mm. in length, and 0·28 mm. in breadth. The oesophagus is short measuring only 0·19 mm. in length. The intestinal caeca are sinuous, arcuate, and extend almost upto the posterior end of the body.

The testes are small, rounded or oval structures with smooth margins, and are situated symmetrically at the antero-lateral regions of the ventral sucker. The left testis measures 0·446 — 0·519 mm. in length, and 0·368 — 0·392 mm. in breadth, while the right one measures 0·431 — 0·519 mm. in length, and 0·294 — 0·346 mm. in breadth. The cirrus pouch is a small, pear-shaped structure situated between the ventral sucker and the intestinal bifurcation. It measures 0·218 — 0·279 mm. in length, and 0·115 mm. in breadth. It encloses a rather large vesicula seminalis and short pars prostatica surrounded with prostatic gland cells. The common genital pore is median behind the intestinal bifurcation.

The ovary is oval and measures 0·345 — 0·488 mm. in length, and 0·337 — 0·4 mm. in breadth. It is median in position, but is obliquely placed at the posterior border of the ventral sucker, which partly overlaps it. The Mehli's gland complex is situated close to the posterior border of the ventral sucker by the side of the ovary. A small receptaculum seminis lies close to the ootype. A Laurer's canal could not be observed in these specimens. The uterus is extensively developed. Its coils are profusely distributed in both extracaecal as well as intracaecal regions from the level of oral sucker upto the posterior end of the body. Distally, the uterus continues into a wide metraterm, which is 0·152 mm. long. A large number of small unicellular glands open into the metraterm. The eggs are oval, operculated, and measure 0·052 — 0·061 mm. in length, and 0·029 — 0·037 mm. in breadth. The vitelline follicles are distributed laterally in two groups on either side. The

anterior groups of the vitelline follicles extend anteriorly upto the level of the cirrus pouch, while the posterior groups do not reach the caecal ends.

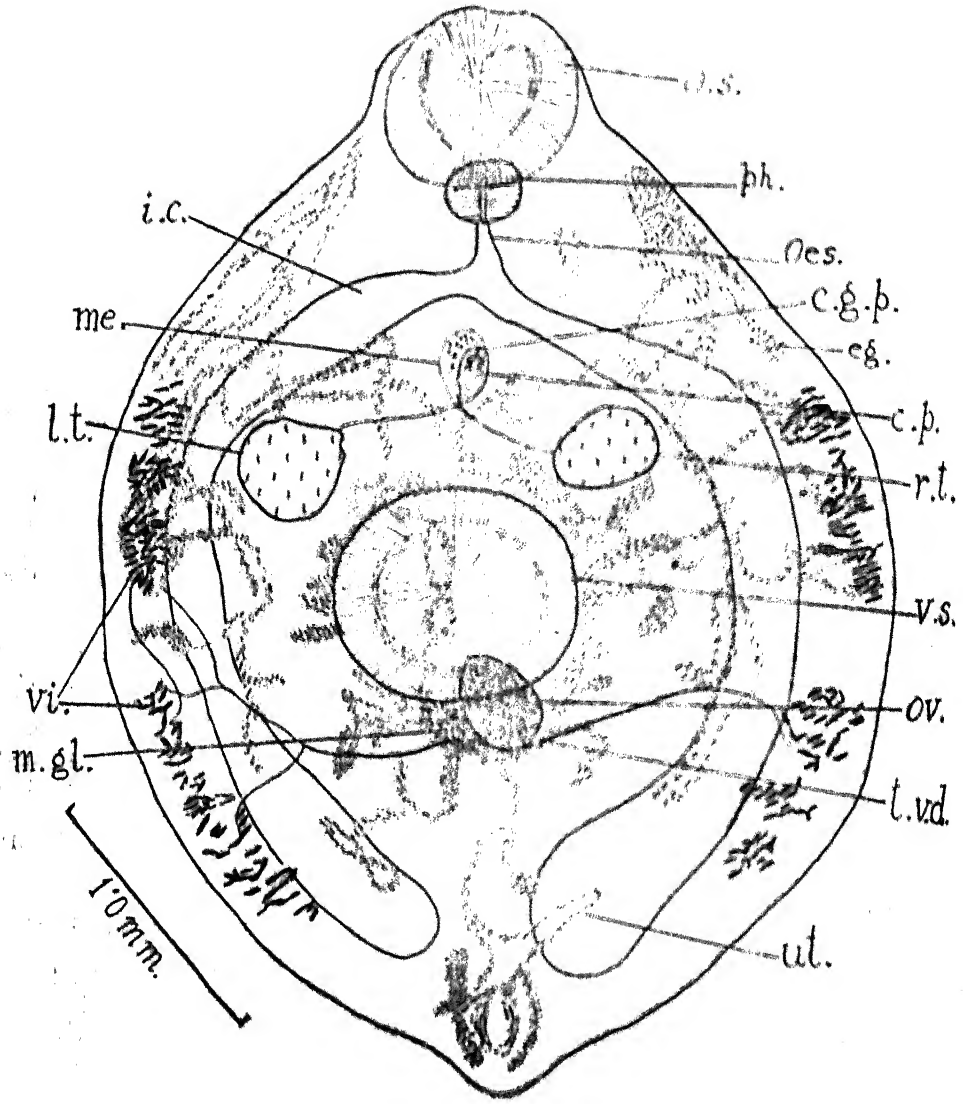

Fig. 1 *Euparadistomum francolini* n. sp. (dorsal view).

The excretory pore is subterminal and leads into a Y-shaped excretory bladder.

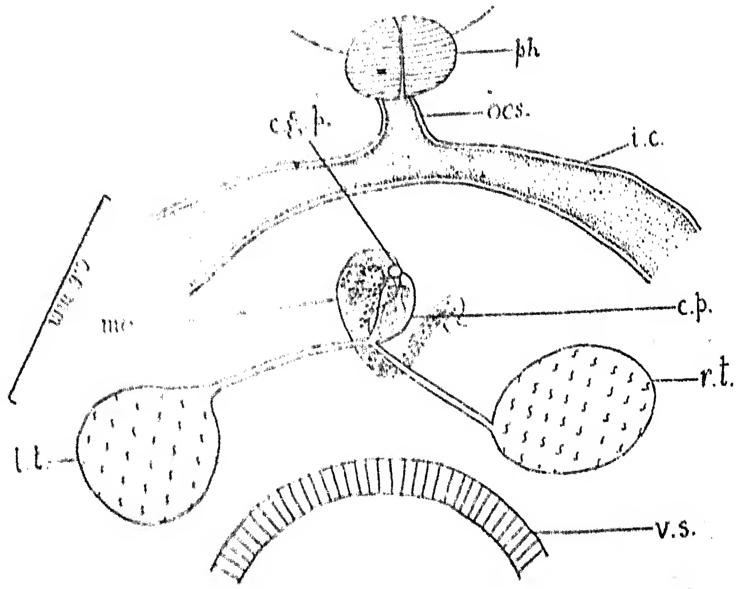

Fig 2. Anterior region showing cirrus pouch and metraterm (dorsal view).

DISCUSSION

Chatterji has recently (1952) suggested to drop the genus *Euparadistomum* Tubangui, 1931 in synonymity with the genus *Platynotrema* Nicoll, 1914. Baugh (1956) has supported this view. Buckley and Yeh Liang-sheng (1958) have, however, revived the genus *Eupara istomum*, and have even created a new subfamily Euparadistominae for its reception under the family Dicrocoeliidae Odhner, 1911. I find myself in perfect agreement with the latter authors in keeping *Euparadisotomum* as a distinct genus.

Of all the species of this genus, hitherto known, the present form resembles more closely to *Euparadistomum paraense* (Jansen, 1941) Travassos, 1944. It can, however, be easily distinguished from this species by the absence of cuticular papillae, presence of unicellular gland cells opening into its metraterm, and by the larger size of its eggs.

EXPLANATION OF FIGURES

c. g. p. —common genital pore; c. p. —cirrus pouch; eg. —eggs; i. c. — intestinal caeca; l. t. —left testis; me. — metraterm; m. gl. —Mehli's glands; oes —oesophagus; o. s.—oral sucker; ov. —ovary; ph. —pharynx; r. t. —right testis; t. vd. —transverse vitelline duct; ut. —uterus; vi —vitellaria; v. s. ventral sucker.

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A REDESCRIPTION OF *PSEUDODISCUS COLLINSI* (COBBOLD, 1875) STILES AND GOLDBERGER, 1910— A COMMON PARASITE OF EQUINES

By

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In a survey of helminth parasites of equines (*Equus caballus orientalis* and *E. asinus*) conducted during routine post-mortem examination, a heavy infestation has most commonly been encountered with this amphistome (Rai and Srivastava), which since 1875, has been recorded from Bengal, Punjab, Uttar Pradesh, Assam and Madras by a number of workers. Bhalerao (1935) gives, in brief, only a few of the diagnostic characters of this species. An allied species, *P. hawkesi* (Cobbold, 1875), also reported as a parasite of equidae but mostly from the South, has recently been recorded from an Indian elephant by the author in a joint paper (Malik *et al*).

The material under study, collected mostly from local ponies used for operative surgery work, has largely been studied from living specimens, both immature and adult, as also from total mounts and serially sectioned stained preparations. The present paper deals with the salient features in its anatomy including the excretory system, which is described herein for the first time, as also the embryonic development studied in a preliminary manner under the laboratory conditions. Such a study, it is believed, is a necessary prelude to a proper understanding of the group of amphistome parasites which, in case of other domestic animals, have of late been receiving greater attention from workers all over the world but the systematics of amphistomes remain even to this day somewhat controversial.

Thirtytwo ponies and five donkeys have so far been examined during the last six months (May, 1958 to November, 1958) and, of these, twentysix among the former and three among the latter were found to harbour the parasite which is usually found between the wall of the caecum and its contents invariably with thick and tenacious mucus around it at the site of its occurrence. Some specimens, however, were also seen in the colon area. During the period May to September, out of six ponies and four donkeys only two animals in each group were found infested and only the adult worms were recovered, but from October onwards, of the twentysix ponies and one donkey, twentyfour of the former and the latter proved positive and, in addition to adult specimens, immature flukes were also met with in large numbers. Practically on all occasions infestation was heavy.

The excretory system is clearly distinct in immature specimens and can readily be studied in all its detail after the worms have been left in normal saline for 24 to 48 hours at room temperature. The visibility of the main ducts in the system is greatly aided on account of the presence of minute granules. The live worms, immediately after collection, were kept in normal saline in petri dishes for five hours at room temperature (maximum 81°F., minimum 76°F and humidity 91%) on October 1,1958, and allowed to lay eggs.

DESCRIPTION

The amphistome, in living condition, has a brick-red colour and a somewhat oval shape with convex dorsal and slightly concave ventral surfaces. The adult specimens, fixed after flattening under pressure between two slides, measure from 8·0 – 10·5 m.m. in length and 3·5 – 5·8 m.m. in breadth, the greatest breadth lying in the region of testes. The body is tapering anteriorly but posteriorly it is rounded. The anterior end has a number of prominent papillae around the mouth opening which is terminal. The oral sucker, measuring 0·41 × 0·69 m.m. in size, is nearly cup-shaped in outline and leads posteriorly into a muscular half-moon shaped structure, measuring 0·75 – 1·14 m.m. in size and situated dorsally to the beginning of oesophagus. The oral sucker and succeeding muscular region together appear like an hour-glass (Fig. 1). On each side there is a globular pouch with weaker musculature and of 0·74 × 1·24 m.m. in dimension with its cavity in communication with that of oral diverticulum. The oesophagus, as stated above, takes its origin from the mouth cavity just behind the oral sucker and at the level of the origin of the diverticula, but passes ventrally as a convoluted tube. It is 2·0 – 2·5 m.m. long, is lined internally with cuticle throughout its length, has a number of unicellular oesophageal glands around it in its course, and immediately behind the level of the two oral pouches enlarges into a well developed muscular bulb before dividing into the two intestinal caeca. The caeca are wavy in their course and terminate near the border of the posterior sucker which is sub-terminal and lies about 0·84 m.m. in front of the posterior extremity. The posterior sucker is rounded in shape and measures 1·14 – 1·42 m.m. in diameter. Testes are intercaecal, symmetrical in position, deeply-lobed, situated near the middle of the body and measure 1·42 – 1·71 m.m. × 1·6 – 1·7 m.m. in size. A prominent vas deferens arises from each and passes forward, the two ducts uniting into a common duct which immediately enlarges into a coiled seminal vesicle lying posterolaterally to the genital cone-slightly muscular structure surrounding a well developed genital-atrium, lying behind the intestinal bifurcation at about 3·25 – 4·3 m. m. distance from the anterior end of the body. There is no cirrus sac. Ovary, 0·28 × 0·55 m.m. in size, is immediately posttesticular but lateral in position, lies in front of the posterior sucker with the shell-gland area, measuring 0·41 × 0·42 m.m. in size, located just behind it. The uterus, after its origin from the shell-gland mass, passes towards middle and then traverses forward in a straight course in the intertesticular space before opening into the genital atrium independently of the male end apparatus through a prominent metraterm. Vitellaria are mostly lateral to the intestinal caeca extending from the level of the intestinal bifurcation upto the posterior level of acetabulum. A few follicles, however, behind the posterior limits of testes extend internally to the caeca. The Laurer's canal opens in front of the excretory pore, which is dorsal in position just behind the posterior limits of the acetabulum and leads into a fairly large excretory bladder which has a somewhat elliptical outline but with a narrower posterior part. The bladder is located dorsally but slightly overlaps the posterior sucker and the two main longitudinal excretory ducts, without any transverse connection between them, open on the antero-lateral aspects of the bladder. Each canal extends from the sides of the bladder and, after a short straight course, before pursuing a forward convoluted course, receives a posterior duct formed from two branches, one coming from the acetabulum and the other from the adjoining area (Fig. 2). At the level of the ovary the longitudinal duct in its anterior course lies internal to the caecum of the side, receives a well-developed tributory also formed from two longitudinal branches—an anterior and the other posterior, which lie just internal to the body-wall of the side and drain out the excretory material from that region of the body. The main duct, however, on each side, after receiving internally smaller branches from the reproduc-

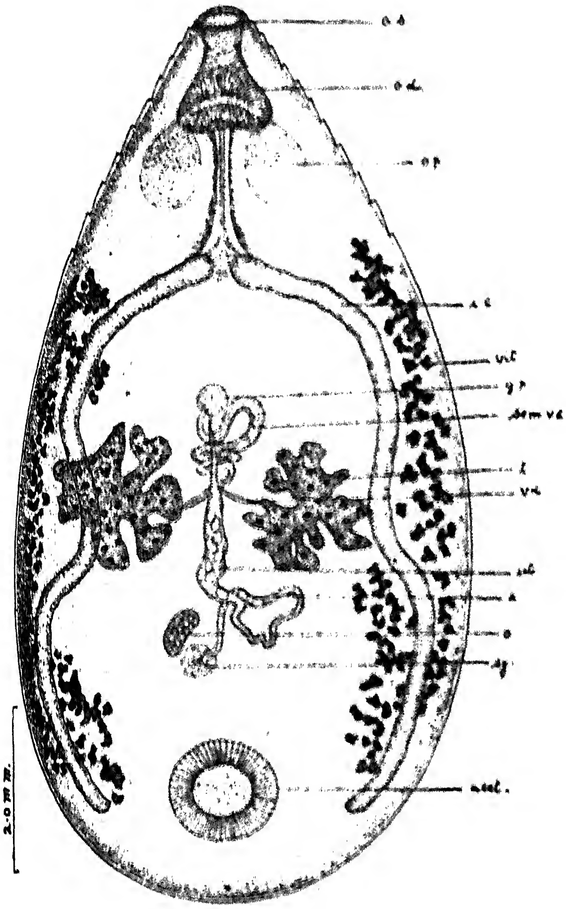

Fig. 1. Entire specimen.

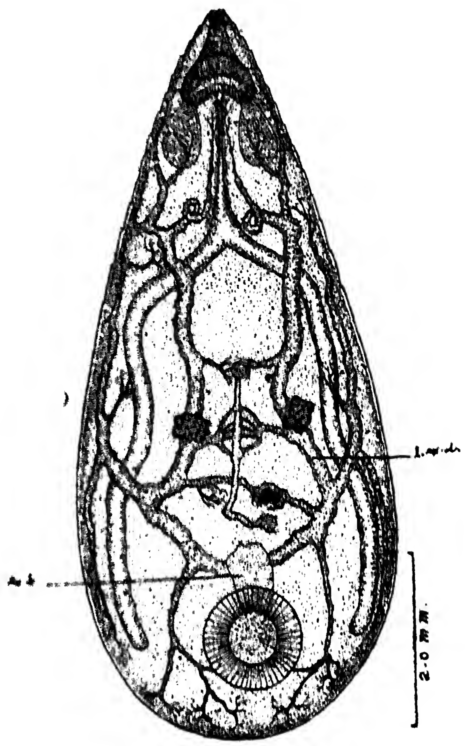

Fig. 2. Excretory system.

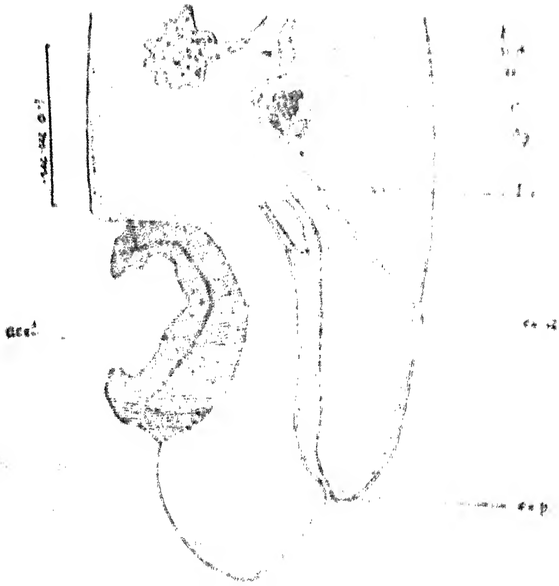

Fig 3

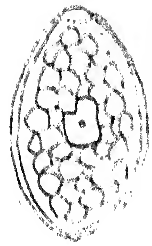

Fig 4

Fig 5

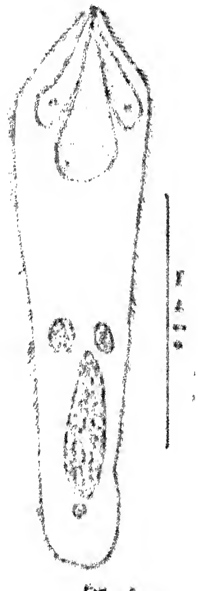

Fig 6

Fig. 3. Reconstructed from longidual sections through acetabulum, excretory pore and opening of the Laurer's canal.

Fig. 4. and 5. Stages in the embyon's development

Fig. 6. Miracidium.

tive organs and genital atrium, crosses the intestinal caecum and at the level of the intestinal bifurcation in its turn is formed from two branches, one on each side of the pouch, the internal having a looped character but the external is formed from two smaller branches, one connected with the pouch itself and the other with the side of the oral sucker.

The freshly laid eggs were nearly of uniform size, operculated and oval in shape measuring 0·14 – 0·16 m.m. in length and 0·09 – 0·095 m.m. in breadth. The posterior non-operculated end, however, is wider and carries a small prominence. Fresh eggs show clearly the single-celled zygote as a distinct area completely surrounded by yolk-cells which, however, leave a very small free area particularly towards the pointed operculated end. The vitelline membrane is distinctly seen. Segmentation was observed to begin on the third day and on the next day the sixteen-celled stage had been reached. Subsequently further traces of segmentation in the developing embryo were not discernable but an irregularly shaped mass of cells, 0·0175 × 0·02 m.m. in size, could be observed (Fig. 4) and later on the 8th day this area showed further growth and measured 0·025 × 0·03 m.m. in size. The differentiation of the embryo into a ciliated structure became apparent on the 16th day with the anterior end, characterised by the presence of a papilla and certain structures that could be easily visible inside the broader anterior part (Fig. 5). These consisted of a pair of penetration gland and the primitive gut with two small masses of germ-cells present posteriorly. The remaining yolk-cells, however, could be seen pushed towards the sides of the developing embryo. The contained embryo later started showing movement of its body and hatching began on 19th day. The activity exhibited in hatching lasted for nearly four minutes which was the time taken by the larva to come out completely since it began pushing the operculum. This embryonic development was studied in October when the range of temperature and humidity conditions were: Maximum temperature 80 – 85°F, minimum temperature 75 – 82°F., humidity 75 – 91%. The miracidia measured 0·225 – 0·25 m.m. in length and 0·045 – 0·05 m.m. in breadth (Fig. 6). Peter (1955) studied the precercarial development of this amphistome from ova obtained from the faeces of an elephant and according to him the miracidium hatches in 17 days.

Pseudodiscus collinsi along with *P. hawkesi* (Cobbold, 1875) described briefly in an earlier joint paper (Malik *et al*) has been included in the sub-family Pseudodiscinae (Nasmark, 1937) of the family Cladorchidae (Southwell) and Kirschner, 1937). There is full agreement between these two species so far as the structure of the oral sucker, its pouches, the genital cone and atrium are concerned and the only difference which is of importance in differentiating the two lies, as already stated in that paper, in the position of testes.

ACKNOWLEDGEMENT

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KEY TO LETTERING

acet. acetabulum, e. egg, ex. b. excretory bladder, ex. p. excretory pore, g. a. genital atrium, g. c. genital cone, i. c. intestinal caecum, l. c. Laurer's canal, l. ex. d. longitudinal excretory duct, met. metraterm, o. ovary, o. d. oral diverticulum, oes. oesophagus, o. p. oral pouch, o. s. oral sucker, sem. ve. seminal vesicle, sg. shall gland, t. testis, u uterus, v. d. vas deferens, and vit. vitellaria.

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STUDIES OF FRESH WATER BOTTOM FAUNA—II

QUALITATIVE COMPOSITION AND VARIATION OF THE AVAILABLE FOOD-SUPPLY FOR FISHES*

By

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INTRODUCTION

In most freshwater stretches some animals have proved themselves successful in passing their life on the bottom. The fundamental importance of these organisms in the economy of the natural waters is that they play an important part in the nutrition cycle of the aquatic organisms and form a good bulk of food of the fishes. As one phase of the investigation of the available food supply for the fish population, an attempt has been made to study the benthic organisms of freshwater bodies. Attention has been given in the recent years to the bottom fauna investigations by the leading limnologists of the world, and the literature built upon this subject in Europe, America and Japan contains important and interesting conclusions.

The work on freshwater bottom fauna (the available food supply for fishes) in India has been more or less completely neglected. Observations made by Bristow (1938), Samuel (1944) and Seshappa (1953) are limited entirely to the marine regions. The author (1956a and 1956b) has given some quantitative data regarding the bottom fauna, and to my knowledge there is no other published data available for Indian freshwater bodies. The present studies were extended to embrace two freshwater lakes and the chief purpose of this work are to give a detailed qualitative picture of the invertebrate fauna, the relative abundance and the seasonal distribution of the organisms. I am thankful to Dr. S. M. Das, Lucknow University for the guidance and keen interest in the identification of the organisms during the course of the work. Thanks are also due to the Lucknow University authorities for providing research facilities and appointing me in the fisheries schemes.

MATERIAL AND METHODS

In order to secure data regular weekly collections were made in the littoral zones of the water bodies with a small scoop-type bottom sampler, which collected a sample of about 10 cm × 10 cm. Generally in all operations, as the mud bottom is soft, the samples came filled to the brim. The samples were emptied into a glass trough, stirred in water, and one tenth part was fractionated out and then transferred to a series of graded fine sieves. The mud was washed with excess water and the organisms were immediately transferred to a wide mouthed bottle containing water. The captured organisms were then preserved in 5% formalin after preliminary indentification in living condition. Some insect larvae were isolated and reared, in the laboratory for identification. The fixed organisms were next identified as far as possible, except some occassional organisms which also live on or in the bottom.

* The result of the examination of the food taken (gut-contents) by some fishes are given in another paper in the series.

Eggleton (1931) recognised three major zones on the lake floor, viz., littoral, sublittoral and profundal. The relative extent of these zones varies to a great degree in different lakes, and in some lakes the whole bottom may be grouped as within the littoral. Muttkowski (1918) proposed several terms to replace those which have been perhaps borrowed from the oceanographers. But his proposals have not yet been adopted by many limnologists. Some others used terms as 'shallow water zone', 'intermediate zone' and 'deep water zone'; while Lundbeck (1925) summarized the classification given by various authors by the bottom hab'tats although leaving out these three terms (littoral, sublittoral and profundal) and compared the extent of these zones as variously defined by himself and by others. And therefore it is evident that no definite agreement has been reached by limnologists regarding this. And thus as recomended by Eggleton (1931) it is better that the same older and more generally accepted terms should be used in the interest of uniformity. Besides, it can be seen that there is no profundal zone present in these water bodies in which the studies were conducted, as these are not much deep.

QUALITATIVE COMPOSITION OF BENTHIC FAUNA

LaMartiniere Lake :

August—In this month three species of oligochaetes, *Aeolosoma bengalensis, Nais pectinata* and *Chaetogaster orientalis* featured mainly in the samples. Some individuals of *Dero limosa* were also seen but rarely. Some leeches were also present. *Chironomus* larvae were present in good numbers and larvae of *Corethra* and *Ictinus* were represented frequently. *Viviparas bengalensis, Viviparae oxytropis, Limnaea* and some bivalves were common in molluscs. Some crustaceans e. g. *Stenocypris, Eucypris* and *Daphnia* were also noticed in the collection of this month.

September—The population of oligochaetes was less as compared to the previous month but the main components of the group were almost the same. *Chironomus* larvae experienced an increase in their number. *Corethra* and *Ictinus* larvae were represented in the samples. Molluscs declined in number and the same species were present as noticed in August. Occasionally some ostracods were also seen in the samples.

October—The same four species of oligochaetes were represented mainly, but some specimens of *Stylaria lacustris* also appeared in this month. Some leeches were also observed in samples. The population of *Chironomus* larvae experienced an increase, but there was no marked change in other insect larvae and ostracods. Molluscs were the same as noticed in September.

November—In this month, although all the same species of Oligochaetes were present, but *Nais pectinata* and *Aeolosoma bengalensis* were more numerous as compared to *Dero limosa, Chaetogaster orientalis* and *Stylaria lacustris.* Some leeches were also present. Larvae of *Chironomus* increased further, while those of *Corethra* and *Ictinus* were scanty. Ostracods were represented by *Stenocypris* and *Potamocypris.* Molluscs were less in number, and *Viviparae oxytropis* were rare.

December—The components of oligochaetes were similar to that of the last month. Some leeches were present, and *Chironomus* shared a good number Larvae of *Corethra* and *Ictinus* were again common along with those of some mayfly. Ostracods were represented by *Stenocypris* and *Eucypris.* A few shrimps were also seen in the collections. In molluscs *Limnaea, Viviparae bengalensis* and bivalves increased in number.

January—Oligochaetes were chiefly represented by *Dero limosa, Nais pectinata* and *Aeolosoma bengalensis*, while other species were observed in less numbers. Few individuals *Branchiodrilus semperi* appeared for the first time in the samples. Leeches were not present in the collections. The population of *Chironomus* larvae showed a fall. Usual insect larvae were noticed without any marked change in their population. *Stenocypris* and *Eucypris* were represented among ostracods. Some shrimps and cladocera were also seen. Molluscs were shared by *Viviparae bengalensis* and bivalves in the collection of this month. Species of *Planorbis compressus* and *Planorbis huttoni* were also obtained in the catch.

February—There was no marked change in the individuals of oligochaetes but their population showed a decline. Leeches were not seen in the samples. *Chironomus* experienced a sharp fall in their number while larvae of *Corethra, Ictinus* and *Dixa* were seen occasionally. The crustaceans did not show any change. Although there was no change in the individual species of molluscs, but *Planorbis compressus* and *Planorbis huttoni* showed a sharp rise in their population. There appeared some statoblasts of Bryozoa in the collections of this month, the chief forms being that of *Pectinatella burmanica*.

March—This month showed no definite change in the components of oligochaetes. Leeches appeared in less numbers. *Corethra* were common while *Chironomus* and *Ictinus* larvae did not appear in collections. Crustacea were represented by the same forms, present in the previous month. The chief component of molluscs were the species of *Planorbis* which showed a further increase in their population. *Viviparae* and *Limnaea* and some bivalves were also represented although in less numbers. Statoblasts of *Stolella indica* were also noticed in the month along with those of *Pectintella burmanica*.

April—The population of oligochaetes increased in this month. Moreover, *Chaetogaster orientalis, Dero limosa, Nais variabilus* and *Branchiodrilus semperi* all shared the samples. A few leeches were present but *Chironomus* were scanty. *Corethra* were common and specimens of *Dixa* were obtained but rarely. Ostracods were not represented while some cladocera and shrimps were noticed frequently. Both species of *Planorbis* maintained a good population but *Viviparae oxytropis* was not seen, while *Limnaea* and some bivalves were present, though in small numbers. Statobasts did not appear in the collections of this month.

May—Oligochaetes were abundant and showed their maximum population during the year, almost all the species being represented except *Nais variabilus*. Leeches were present although in small numbers. *Chironomus* exceeded in number, and no other insect larvae were noticed. Ostracods and cladocera did not appear in this month, but shrimps showed a rise in their population. *Planorbis* experienced a sudden decline while *Viviparae bengalensis* shared in the sample in smaller numbers. Some forms of bivalves were also observed but in very limited numbers.

June—Oligochaetes were still abundant, and except *Nais variabilus* and *Dero limosa* all other species were represented, but leeches were absent. *Chironomus* were common, but no other insect larvae were noticed. *Planorbis* appeared to have disappeared while other molluscs showed no change in their individuals. Shrimps and some cladocera were also present in the collections.

July—Oligochaets did not show any well marked variation either in the individuals or in the population as compared with the previous month. Some leeches appeared, during the month and *Chironomus* were also present. Some shrimps and cladocera also shared the bottom catch. In molluscs *Limnaea, Viviparae bengalensis, Viviparae oxytropis*, and some bivalves were represented during the month.

Thus it is evident that the bottom fauna of LaMartiniere is qualitiatively diversified and rich. Of the main components freshwater oligochaetes, *Chironomus*, snails, bivalves, statoblasts, ostracods, cladocera and nymphs of dragonfly and mayfly, along with larvae of dipterus insects (*Corethra, Dixa*) constituted the main bulk, of bottom fauna. Besides, these organisms there were also present certain freshwater sponges, occasional *Hydra*, sometimes bryozoa colonies and the statoblasts of different species, some free living nematodes and rarely *Planarians*, were also obtained.

Kathauta Lake :

August—In this month, the bottom samples consisted chiefly of oligochaetes, of which *Aeolosoma bengalensis* and *Chaetogaster orientalis* were most prominent. Other forms present were *Nais variabilus* and *Dero limosa*, although in very small numbers. Among insects, larvae of *Chironomus, Corethra*, were common while some dragonfly, mayfly, and some beetle larvae were also taken during this month. Among molluscs, *Planorbis compressus* was frequently found along with some bivalves and some gastropods, viz., *Viviparae bengalnesis* and *Limnaea.*

September—In the species of oligochaetes, which were abundant, *Aeolosoma bengalensis* and *Chaetogaster orientalis* were largely presented, though *Dero limosa* and *Nais variabilus* were in no way rare. *Chironomus* featured prominently among insect larvae while the *Corethra* showed a thin population in this month. Insect larvae specially caddisfly and beetles along with nymphs of dragonfly and mayfly were represented in good numbers. Stray forms of ostracods represented by *Eucypris* and *Cypris* were also noted. There was no change in the species of *Planorbis* and *bivalves.* But among other gastropods, *Viviparae oxytropis* were also seen in addition to the forms present in the previous month.

October—Although the population of the oligochaetes was comparatively thinner than that of September the species of *Aeolosoma bengalensis* was much commoner than *Chaetogaster orientalis.* Both *Dero limosa* and *Nais variabilus* were also seen although in reduced numbers. The characteristic feature of the samples in this month was the increase in the number of *Chironomus* and *Corethra* larvae. Nymphs of mayfly, larvae of caddisfly and some beetles were specially common ; while that of dragonfly were by no means rare. Ostracods were remarkably rare. Among molluscs, *Planorbis compressus* was represented by a few examples, while *Planorbis huttoni* appeared for the first time in the collections. There was no marked change in the components of bivalves and other gastropods from that noticed in September.

November—In oligochaetes, *Aeolosoma bengalensis* was more common while *Chaetogaster orientalis* was comparatively rare. But this compensated by the appearance of *Branchiodrilus semperi*, although in limited numbers. Both *Dero limosa* and *Nais variabilus* were represented in the samples. Among insects, *Chironomus* and *Corethra* larvae featured greatly. Mayfly and dragonfly nymphs were more common in this month as compared to the larvae of beetles and caddisfly. *Planorbis compressus* and *Planorbis huttoni* along with the bivalves appeared as usual. Other gastropods were reduced in numbers and were chiefly represented by *Viviparae bengalensis* and *Limnaea*, the former being significantly casual.

December—Although the population of oligochaetes suffered much in this month, the general condition of its components remained almost similar to that of November. The larvae of *Chironomus* were very much conspicuous along with that of *Corethra.* Other insect larvae were represented by nymphs of mayfly and dragonfly. In this month, some forms of the dipterus larvae were also taken from the samples along with those of caddisfly and beetles. Stray examples of ostracods also appeared

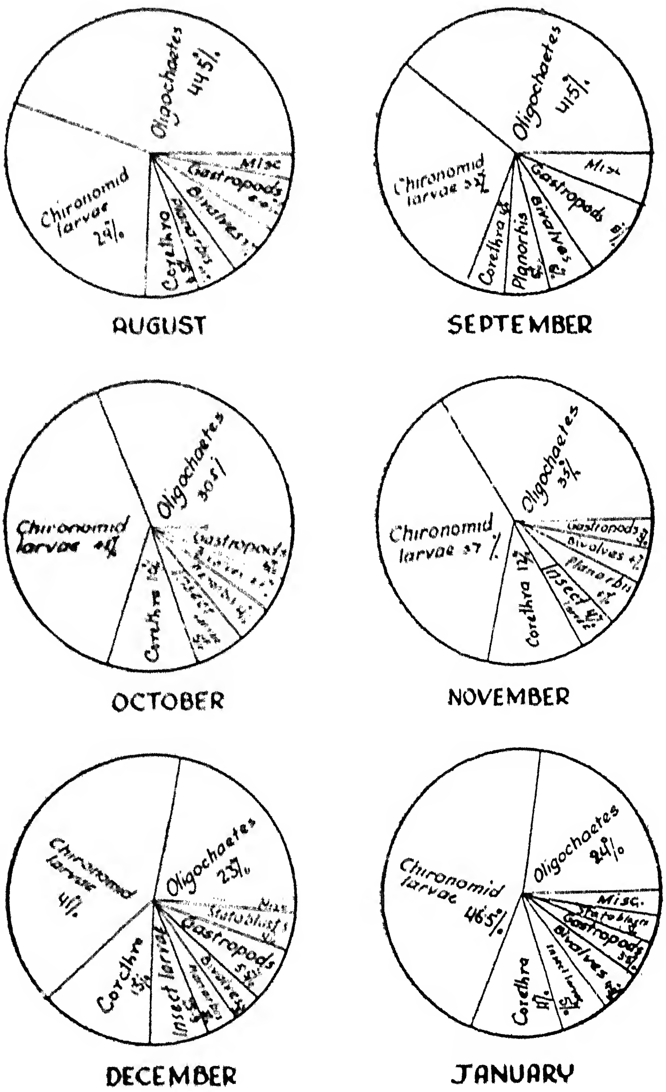

PLATE 1. Diagram showing the composition of bottom fauna in Kathauta from August to January.

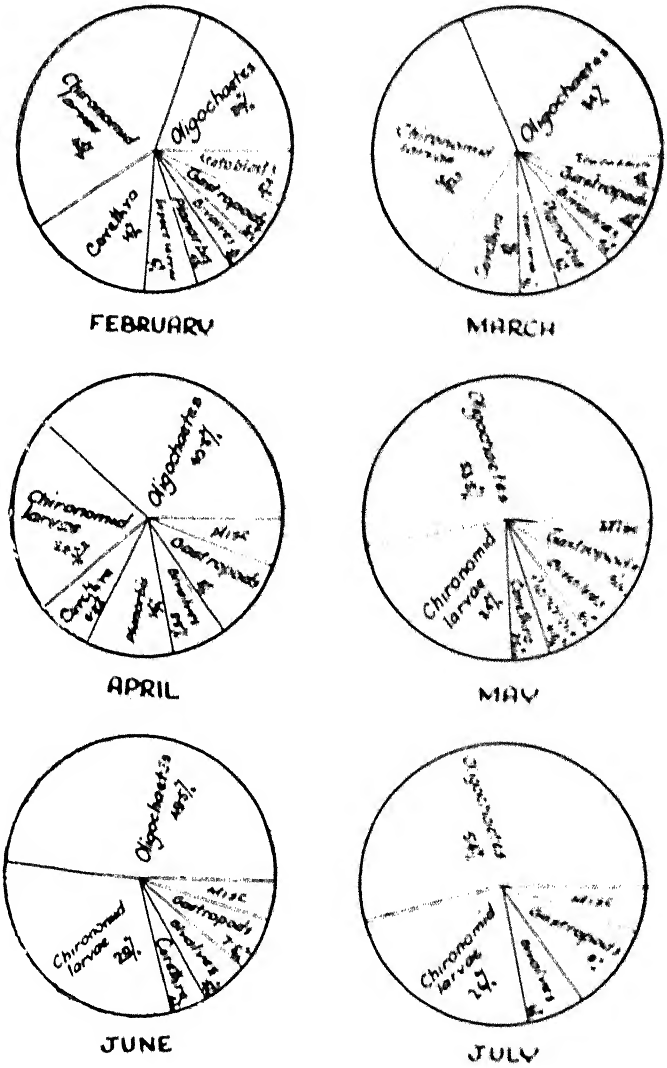

PLATE 2. Diagrams showing the composition of bottom fauna in Kathanta from February to July.

in this month. There was no marked change in the components of molluscs from that of the previous month. Statoblasts of *Plumatella fruticosa* and *Plumatella punctata* also appeared in this month.

January—There was no marked change in the number of oligochaetes, *Aeolosoma bengalensis* and *Branchiodrilus semperi* featured prominantly, while *Chaetogaster orientalis* appeared to have disappeared from the samples. *Nais variabilus* and *Dero limosa* were present but only in small numbers. The *Chironomus* larvae exhibited a very good number in this month, while *Corethra* and *Dixa* were also commonly seen. The nymphs of dragonfly, mayfly and caddisfly larvae appeared in this month in almost equal numbers. The ostracods were seen occasionally. Among molluscs *Planorbis* became somewhat occasional, while bivalves and other snails showed no change in their components. Statoblasts were represented as in the month of December.

February—Among oligochaetes, *Branchiodrilus semperi* and *Aeolosoma bengalensis* were more common. *Dero limosa*, *Nais variabilus* were rare. *Chironomus* and *Corethra* were presented conspicuously, while in other insect larvae, dragonfly and caddisfly forms were rare, but the remaining examples, seen in January being present. Among molluscs there was no special variation. The statoblasts of *Plumatella punctata* appeared more in number than *Plumatella fruticosa*.

March—The characteristic feature of the bottom fauna in this month was the great increase in the number of the oligochaetes. Moreover, in addition to *Aeolosoma bengalensis*, *Branchiodrilus semperi*, *Dero limosa*, and *Nais viriabilis*, examples of *Stylaria lacustris* were also taken from the samples, although in very reduced number. Stray forms of *Chaetogaster orientalis* were also seen in the collections. Among insects, larvae of *Chironomus* were conspicuously common while those of *Corethra* were seen comparatively less in number. Dragonfly, mayfly and *Dixa* larvae were significantly scanty. But beetle and caddisfly larvae were by no means rare. In molluscs, *Planorbis huttoni* became more common as compared to *Planorbis compressus*. Bivalves and other gastropods did not show any well marked differenciation. Statoblasts of *Plumatella punctata* and *Plumatella fruticosa* were common.

April.—The oligochaetes became more numerous and almost all the species, viz., *Aeolosoma bengalensis*, *Branchiodrilus semperi*, *Chaetogaster orientalis*, *Dero limosa*, *Nais variabilus* and *Stylaria lacustris* were represented in the samples. But the last three froms were significantly more common. Among insect larvae, *Chironomus* and *Corethra* featured chiefly. The dragonfly and mayfly nymphs were conspicuous by their rarity. But some beetle and caddisfly larvae, were present. *Planorbis huttoni* was more common than *Planorbis compressus*, in this month also. Bivalves, were as usual but among gastropods the *Viviparae bengalensis* appeared in large numbers, while *Limnaea* was comparatively rare. Statoblasts were presents as in the last month.

May—Oligochaetes were very much conspicuous due to their abundance and all the species reported in April, were present in this month also. Insect larvae were represented mainly by those of *Chironomus* and *Corethra* although their number was reduced to a great extent. Other insect larvae were very rare, only some beetle larvae were seen occassionally. There was no well defined variation in the components of molluscs and statoblasts of only *Plumatella punctata* were taken from the samples.

June—Among oligochaetes, *Dero limosa*, *Nais variabilus* and *Stylaria lacustris* featured prominantly as compared to the *Branchiodrilus semperi*, *Aeolosoma bengalensis* and *Chaetogaster orientalis*. Insects featured chiefly by *Chironomus* and *Corethra* larvae were

also taken from the samples but were not so common as in previous months. Other insect larvae were represented chiefly by those of beetles. *Dixa* larvae were seen in this month again. No well defined differentiation in the composition of molluscs was noted. Statoblasts became particularly wanting in the collections of this month.

July—Oligochaetes were numerous but they did not show any marked fluctuation in their components. Among insects *Chironomus* larvae were again prominent. Larvae of *Corethra* and *Dixa* along with those of dragonfly, and beetles were observed in small numbers. *Planorbis* were significantly rare and only *Planorbis huttoni* were taken from the samples. The bivalves and other gastropod were more common than in the previous months. Statoblasts appeared to have disappeared completely.

In addition to the forms described above there were present some other organisms. But these forms did not appear regularly. Among these were some naidids, very rarely a turbellarian, fragments of a bryozoan and some portion of freshwater sponge some *Hydra* and watermites which were noticed casually.

DISCUSSION

Qualitative variations :

On a qualitative basis the bottom fauna of LaMartiniere lake makes up a typical littoral fauna and includes representatives of *Chironomus*, *Corethra*, *Dixa*, and mayfly and dragonfly larvae among insects ; *Aeolosoma*, *Branchiodrilus*, *Chaetogaster*, *Dero*, *Nais*, and *Stylaria*, among oligochaets ; *Stenocypris* and *Potamocypris* in ostracods and *Viviparae*, *Limnaea*, *Planorbis* and some bivalves among molluscs. While in Kathauta lake there were present certain beetles and caddisfly larvae among the insects along with the forms noticed above. In addition to these forms fragments of bryozoa, fresh water sponges, *Hydra* and watermites were noticed occasionally in both. Statoblasts of bryozoa were also collected from both the water bodies. This is indeed a rich bottom fauna when compared with the observations of Annandale (1919) from certain small streams in Bombay in which he found only small white dipterus larvae of the family Chiornomidae and a shelled thick unionid. No other observations on bottom fauna are available for Indian freshwaters.

However, similar studies made in foreign countries compare well with the present observations. Valle (1928) while making ecological studies of bottom fauna of the lakes north of Lodega lake divided them into three ecological categories and found the first group of lakes with abundant oligochaetes and Chrinomidae ; the second group were less rich than group first ; while the third lake group had oligochaetes rare but *Pisidium* and *Chironomus* were dominant. Eggleton (1931) working on Douglas Lake in U. S. A. noted *Corethra*, *Chironomus* and *Protenthes* among the insects ; *Limnodrilus* among the oligethaets ; and *Pisidium* among molluscs. He further compared these qualitative data with that of other North-American lakes and found that the profundal fauna of Douglas lake resembles more closely in qualitative sense to that of lakes, Mendota, Wawasee, Winnebago, Simcoe and Okoboji.

Miyadi (1931) while making investigations on bottom fauna of Japanese lakes found marked differences in the character and distribution of bottom fauna. He stressed that *Chironomus* larvae contributed the dominant element of the bottom population in the deeper lakes, while *Corethra* were also represented in some. Cronk (1932) found in Shakespeare Island lake, (Ontario) molluscs, crustacea, diptera, ephemeroptera, odonata, trichoptera, coleoptera, oligochaeta and hirudinea as common representative of the fauna. Humphries (1936) investigated profundal and sublittoral fauna of Windermere and found *Pisidium*, Chironomidae and oligochaeta

to be abundant, which were supplemented by ephemeroptera, trichoptera and neuroptera. Calhoun (1944) found that the bottom fauna of Blue lake at depths greater than four meters was limited to *Chironomid* larvae, *Gammaras*, turbellarians and *Tubifex* worms.

It is, however, clear that if the differences of the species are not taken into consideration, and only genera are considered, then the bottom fauna of the LaMartiniere is practically the same as that in Kathauta. Moreover it is also concluded that mainly *Chironomid* and oligochaetes along with molluscs constitute the bottom fauna of these water bodies in general. The taxonomic characters of the organisms in the two water bodies did not show much marked difference.

Considering the number of species present in LaMartiniere it is seen that oligochaets recorded seven, insects four, ostracods three and molluscs seven along with two types of statoblasts and some species of *Hydra*, nematodes, and *Planarians* which appeared occassionally. While in Kathauta, oligochaets shared six, insects seven, ostracods two and molluscs five species. Two species each of *Hydra* and bryozoan statoblasts along with some species of turbellarian and watermites were also noticed casually in Kathauta. Similar variations in the number of species have been worked out by Baker (1918) who found 10 species of cladocera, 1 copepod and 2 ostracods occurring as bottom catch of Oneida lake, New York. Adamstone and Harkness (1923) while studying the bottom organisms of Lake Nipigon, reported large numbers of molluscs along with 4 nematods, 5 specimens of acanthocephala, several oligochaetes, 8 hirudinea, 4 cladocera occasionally ostradods, 3 amphipoda, along with larval and nyphal stages of several insects belonging to the orders-ephemerida, odonata, neuroptera, trichoptera, coleoptera, diptera (chiefly Chironomidae). Rawson (1930) studied the benthic microfauna of lake Simcoe Canada, and noticed a population composed of 2 turbellaria, some copepods, nauplii and several ostracods, 1 gastrotrichia, 1 tradigrade and 3 watermites. Cronk (1932) investigated the bottom fauna of Shakespeare Island lake and found that the organisms constituting the benthic fauna belonging to chiefly four groups, mollusca, crustacea, insecta and oligochaeta. Moreover he listed 20 molluscs, 2 crustacean (amphiphod) 12 diptera, 6 ephemeroptera, 5 odonata, some trichoptera, 2 coleoptera and few representative of neuroptera among insects, along with those 8 hydracarina and some oligochaetes. In addition to these groups some hirudinea and nematoda, fragments of sponges, a few *Hydra*, one *Planaria*, parts of other insects, and some fish fry were also reported. Berg (1938) recorded the greatest variety of forms about 29 species in littoral zone. Moore (1939) reported from Douglas lake, nematoda and rotatoria 28, gastrotrichia 2, oligochaeta 8, cladocera 14, copepoda 11, ostracoda 11, and acarina 10.

From the present observations it is established that the LaMartiniere lake has more species as compared with that in Kathauta lake, as well as certain other lakes of other countries. The total number of individual species varies remarkably in these water bodies from those recorded by biologists from other fresh water bodies in various parts of the world.

There are remarkable differences in the taxanomic distribution of the bottom forms studied here, with those reported from other countries abroad. As noted above, Valle (1928) Miyadi (1931), Miyadi and Hazama (1932), reported *Chironomus* forming the major portion of the bottom fauna; while Cronk (1932) established the preponderance of small molluscs in the littoral zones. Humphries (1936) found *Pisidia*, Chironomidae and oligochaetes to be abundant, and I have found oligochaetes and *Chironomus* larvae constituting the main bulk of the bottom samples in these fresh water bodies in India.

Seasonal variations :

With the succession of seasons there seems to occur changes in the distribution and population of the benthic organisms. The continuous year round study gives a clear understanding of these fluctuations, of the various components inhabiting the bottom, as detailed in following paragraphs.

Oligochaeta :

They formed a noteworthy feature of the bottom throughout the year in both LaMartiniere and Kathauta. These were obtained in abundance during the months of August and September in LaMartiniere, but their numbers were depleted in the following months, till they reached their lowest in February. In April and May, they experienced an increase in population which attained a maximum in May and remained high in the subsequent months of June and July. While in the Kathauta they were appreciably abundant in the months of August to November, but they showed a decline in December and were at their lowest in February. Later, their number increased considerably in the months April to June and finally encountered the highest in July. Moreover, it has also been noticed that their number was remarkably higher in LaMartiniere as compared to the Kathauta lake.

Insecta :

Among insects, the most common and predominant of all were the larvae of *Chironomus*. In LaMartiniere they appeared in large number in the collections of September to January but their maximum concentration was recorded in November. Later from February there was a well marked fall in their population, till finally they reached the lowest in April and their number was lower still in the months May to July. On the other hand, *Chironomus* larvae were common in Kathauta during the months August and September after which there was a marked increase in their number and they became abundant in the months October to December. Lastly *Chironomus* larvae predominated in the months January and February, but declined to some extent in the remaining months upto July.

The larvae of *Corethra*, which formed an important constituent of the bottom fauna of Kathauta were seen in comparatively less numbers in the samples from LaMartiniere. They were common in August and September in Kathauta and increased further in October, and became fairly common during the months of November to February. But they showed a decrease in their population in the subsequent months, till finally they became appreciably low in July.

The nymphs of dragonfly, mayfly, and caddisfly along with some beetles were also taken from the collections, both from the LaMartiniere and the Kathauta, during the year, but their number increased during the winter months.

Crustacea—Cladocera were seen in the LaMartiniere in small numbers throughout the year. But were significantly absent in Kathauta. Ostracods were also present in good numbers during the months September to March later their number decreased in following months in LaMartiniere. While in Kathauta their population was very thin and they appeared occasionally.

Molluscs :

In LaMartiniere bivalves and gastropods were observed throughout the year, the bivalves being common during the months August, December, February, June and July. The gastropods were plenty in number in the months of August to

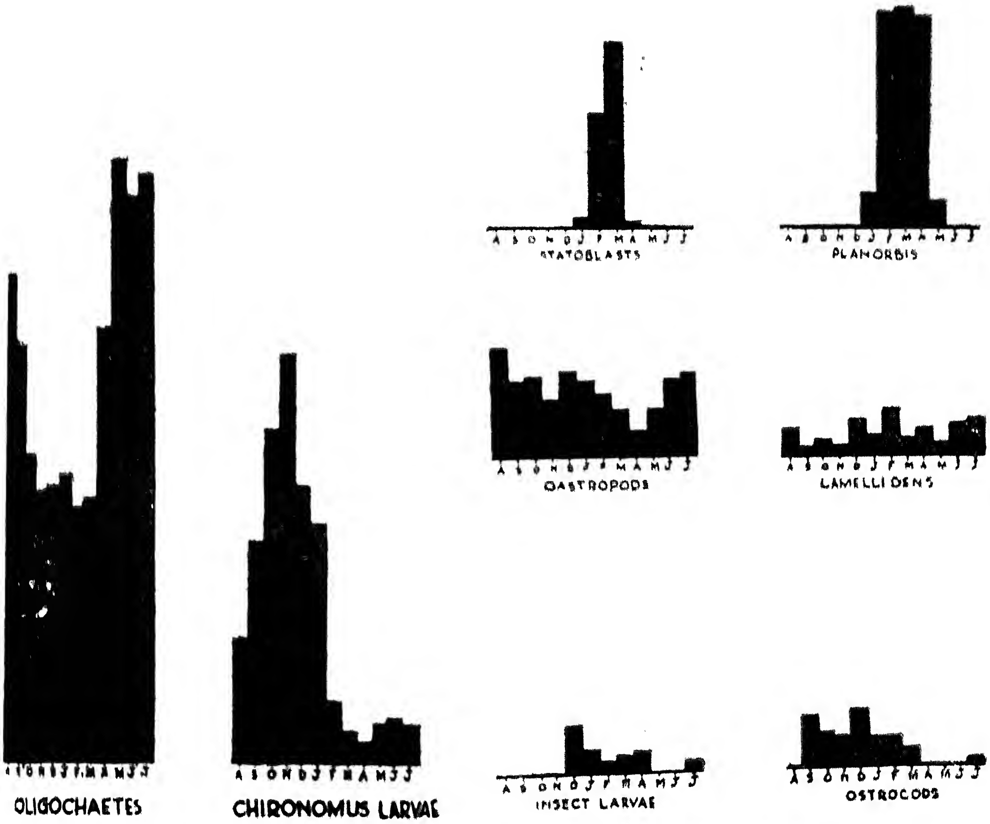

PLATE 3. Histograms showing the seasonal variations of benthic organisms in LaMartiniere. (Letters A to J denote months from August to July).

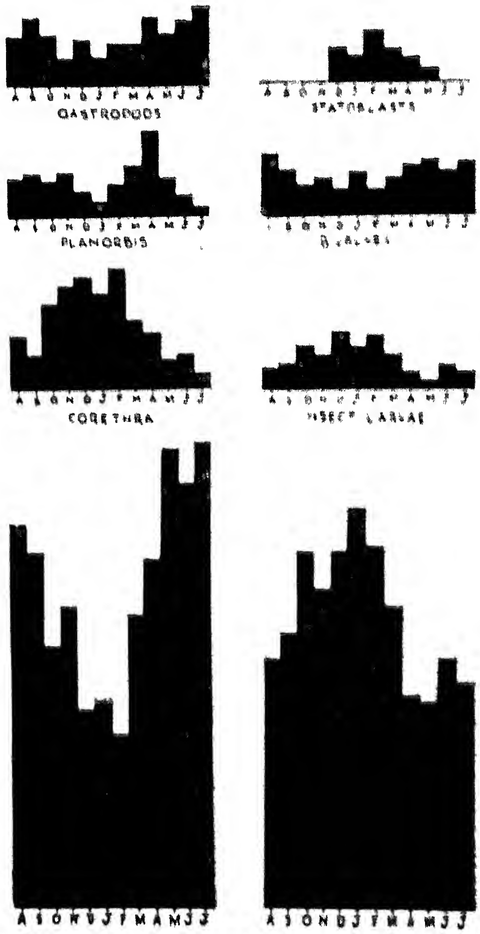

PLATE 4. Histograms showing the seasonal variations of the benthic organisms in lake Kathauta. (Letters A to J denote months from August to July).

February and then during June and July. *Planorbis* which appeared in January increased in number during the months February to April and finally were reduced in May. On the other hand in Kathuta bivalves were taken throughout the year and were more common in the months of August and September, and April to July. Gastropods were also represented in good numbers during the months August to October and April to July. *Planorbis* appeared throughout the year as compared to LaMartiniere although in limited numbers, except in April when they increased considerably. The statoblasts of bryozoa, formed a very common feature in the catches of LaMartinere during the months of February and March, while in Kathauta these were represented during the months December to May, only in smaller numbers.

SUMMARY

The paper presents the result obtained from the regular studies carried out on the qualitative composition and variations in the benthic organisms which form a good source of available food supply for fishes in bottom zone.

The bottom fauna is rich and revealed varied components. In LaMartiniere the number of oligochaete species present were 7, insects 4, ostracods 3, molluscs 7, and bryozoan statoblasts 2, while in Kathauta oligochaetes shared 6, insects 7, ostracods 2 and molluscs 5.

The seasonal abundance of the componets of the bottom fauna shows that ologochaetes dominated the samples throughout year and their maximum population was noticed in June in LaMartiniere. In Kathauta also they appeared in good numbers throughout and their highest number was found in July. *Chironomus* larvae were common throughout the year and attained the highest in November in LaMartiniere and January in Kathauta. Other insect larvae were present in good numbers, during winter months in both the lakes. Bivalves showed the maximum number in February; gastropods in August and *Planorbis* during the month of March in LaMartiniere. In Kathauta bivalves attained highest in August; gastorpods in July and *Planorbis* in the month of April. Bryozoan statoblasts were obtained in highest numbers in March in LaMartiniere and in February in Kathauta lake.

The ologochaetes, insect larvae and molluscs form the main bulk of the bottom catches. If the differences of the species are not taken into consideration and only genera are considered then the fauna of these two lakes appear identical.

Moreover, the avilable food supply for the fishes in bottom zone is not uniformly distributed throughout the year in every stretch of water.

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STUDIES ON FRESH WATER BOTTOM FAUNA—III

THE CORRELATION BETWEEN BOTTOM FAUNA AND THE FOOD OF FISHES*

By

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INTRODUCTION

Biologists all over the world agree that the fishes have specific affinities to the different zones of the water bodies. In India Mookerjee and Das (1945), Bapat and Bal (1950), Pillay (1953) and Sarojini (1954) considered the habits and the food of the fishes which feed in various zones. Das and Moitra (1955) have also tried to establish a relation between the type of fish-food and the feeding habits of certain fishes. Similarly, Adamstone and Harkness (1923) found that the common white fish, of lake Nipigon feeds exclusively on the bottom organisms. Adamstone (1924) recorded for larger specimens of perches that their food consisted mostly of the benthic forms. Rawson (1930) and Hiatt (1944) have also tried to investigate the food of some bottom feeding fishes.

During the present observations an attempt has been made to find out the correlation between the available fish-food in the bottom zone of the lakes and the food consumed in nature by the fishes, *viz.*, *Lepidocephalichthyes guntea*, *Nemachilus botia*, *Nemachilus zonatus*, *Clarius batrachus*, *Heteropneustis fossilis*, *Bagarius bagarius*, *Rita rita*, *Ophicephalus punctatus*, *Labeo calbasu*, *Botia dayi* and *Cirrhina mrigala*. The lake bottom, which harbours a good assemblage of burrowers, clingers, crawlers and hiders among the bottom materials, furnishes a rich source of food supply for the fishes. And as an important phase of the investigation of the available food supply for the fish population, a year round study of the benthic fauna has been carried out along with the regular analysis of the gut contents of the fishes. I am grateful to Dr. S. M. Das for the guidance, and encouragement during the course of the studies. Thanks are also due to Lucknow University authorities for providing research facilities and appointing me in the fisheries schemes.

DESCRIPTION OF THE WATER BODIES EXAMINED

The present studies were extended to embrace two important water bodies, LaMartiniere and Kathauta lakes. The Kathauta lake is situated on the Lucknow-Barabanki road at a distance of about nine miles from the University of Lucknow. During monsoon months the water level touches the highest point which generally falls during the months July to September. In about 50 per cent of the area of the lake, the water was 20 to 30 feet in depth whereas 20 per cent was between 10 to 20 feet while the rest was hardly 5 feet deep. But the level

* The results of qualitative and quantitative studies on the available fish-food supply (Bottom-fauna) for fishes are detailed in Part I and II papers in the series.

of the water receded gradually and reached to the minimum during summer month that is May and June being about 14·5 feet. During the summers the water level declined and a broad strip of lake bottom was left exposed on the margin of the lake. The increase in the water quantity during monsoon is due to the inflow of water from the surrounding fields and secondly because of the local rains of which the lake becomes the catch basin. The fall in the water level during summer appears on account of the evaporation and draining out of the water in the neighbouring fields with several artificial methods for irrigation purposes. The aquatic vegetation showed a luxurient growth between 2 to 18 feet depth. The maximum length of the lake is 5250 feet while its width measures only about 390 feet. The maximum depth is about 35 feet.

LaMartiniere is located three miles away from the University. The water registers a high level during monsoon but it experiences a gradual decline in winter, till finally it reaches the minimum level in summers and a long strip of land is left exposed. With the approach of monsoon the water level registered an increase, due to the rains and local drainage of the water. It holds a large population of freshwater fishes. The maximum length and width of LaMartiniere is about 1800 ft. and 315 ft. respectively. And the maximum depth recorded was 24 feet.

These water bodies comprised (1) The mariginal zone of varying width that encircles the lake. It is covered with floating and submerged dead and living plants along with several attached and hiding organisms. (2) Intermediate zone, on the inner edge of the marginal zone the water thoughless pure than the central part is clear ; submerged thickets of such plants such as *Ceratophyllum*, *Hydrilla*, *Utricularia*, flourish, and those of *Vallisnaria* and *Hydrilla* being particularly laxurient. Its boundry whether inwards or outwards are not well defined. (3) Central zone where the water is of perfect transparency has plankton along with the plants growing up out of the water or floating on the surface and (4) Bottom zone which harbours a good amount of fauna coupled with submerged aquatic plants.

The bottom zone of these water bodies consists mainly of mud, which contains varied amount of organic detritus. The colour and odour of the mud varied slightly. The rate of settling when the mud was stirred up also varied to certain extent. As the bottom forms immediate environment of the benthic organisms as well as of the fishes, it is very essential to know the nature of the bottom on which the productivity of these largely depends.

EQUIPMENT AND METHODS

Fishes were obtained from the regular fish hauls which were made with the help of a cast net along with the collection of the bottom samples. The fishes were measured, weighed and identified in the laboratory. The abdomen of each was then opened and the fishes were fixed in 10% formalin for further observations of the gut contents. When examining the food consumed, the stomach and the intestine was carefully removed and opened with the help of fine scissors. The contents were washed out with water and collected in a clean petri-dish. All the animal and plant material were identified and counted under microscope. In order to secure data for the bottom fauna, regular collections were made with the help of scoop type bottom sampler (Srivastava 1956), from the same waterbodies, the fishes were caught. The percentage composition of bottom was calculated on the lines mentioned in part, 1, of the present series.

ANALYSIS OF GUT-CONTENT OF THE FISHES

Fishes examined	Major items in the gut contents	Remarks
Clarias batrachus	1, 2, 3, 6, 8, 10, 13	Bottom predator
Heteropneustes fossilis	1, 2, 4, 7, 8, 10, 13	Do
Labeo calbasu	11, 12, 13	Bottom feeder
Rohtee cotio	1, 2, 5, 8, 12, 13	Do
Ophiocephalus punctatus	1, 2, 3, 6, 7, 9, 10	Predator
Cirrhina mrigala	11, 12, 13	Bottom-coloumn feeder
Bagarius bagarius	1, 2, 4, 5, 7, 10, 13	Do
Rita rita	1, 2, 3, 4, 5, 8, 9, 10	Bottom feeder
Nemachilus zonatus	4, 11, 12	Do
Nemachilus botia	4, 11, 12	Do
Lepidocephalichthyes guntea	1, 4, 11	Do
Botia dayi	4, 11	Do

1, Larval stages of insects, 2. Insects and their parts, 3. Shrimps, 4. Copepods and cladocera, 5. Statoblasts, 6. Molluscs, 7. Water-mites 8. Oligochaetes, 9. Small fishes, 10. Fish-fins and scales, 11. Unicellular and multicellular algae, 12. Parts of aquatic plants 13. Detritus and debris.

On the basis of the examination of the gut contents of these fishes it is noticed that the food taken by them consisted largely, animals present in the bottom fauna catches along with the parts of the roots, stems or leaves of the hydrophytes collected from the bottom zones and mud.

ANALYSIS OF THE BOTTOM FAUNA

(a) *Qualitative composition*

Srivastava (1956a, 1956b) has given some details of the organisms found in the bottom zone of the water bodies in consideration. On a qualitative basis the bottom fauna of LaMartiniere lake makes up a typical littoral fauna and includes representatives of : *Chironomus*, *Corethra*, *Dixa*, mayfly and dragonfly larvae among insects ; *Aeolosoma*, *Branchiodrilus*, *Chaetogaster*, *Dero*, *Nais*, *Stylaria*, among oligochaets ; *Stenocypris* and *Potamocypris* in ostracods and *Viviparae*, *Limnaea*, *Planorbis*, and some bivalves among the molluscs. While in Kathauta lake there were present certain beetles and caddis fly larvae among the insects along with the forms noticed above. In addition to these forms fragments of bryozoa, fresh water sponges, some *Hydra* and watermites were noticed occasionally. Statoblasts of bryozoa were also collected from both the water bodies. This is indeed a rich bottom fauna when compared with the observations of Annandale (1919) from certain small streams in Bombay in which he found only small white dipterus larvae of the family Chironomidae and a shelled thick unionid. No other observations on bottom fauna are available for Indian freshwaters.

(b) *Quantitative variations*

In order to have a clear idea of the magnitude of the bottom faunal fluctuations, observations made on the total catch along with the variation of the individual groups lead to the following original results.

Total volume

The total catch in LaMartiniere of the bottom fauna was higher during the months of August and September because of the large population of oligochaetes. Then there was noticed a decline in the total volume in the subsequent months till finally it touched a minimum level in the month of January. But it experienced a gradual rise in bulk during the period February onwards, and established the highest volume in June and July with the abundance of oligochaetes again. While in Kathauta the total volume of the bottom fauna was comparatively poor in August and September, but showed a slight increase during October and November. The total catch suffered an appreciable loss with the approach of winter and was the lowest in February. But, again a gradual increase in the population of the organism compensated the loss and the total volume encountered an increase in the month of May and recorded the highest during June. The total catch was comparatively higher in the LaMartiniere than the Kathauta.

Percentage composition

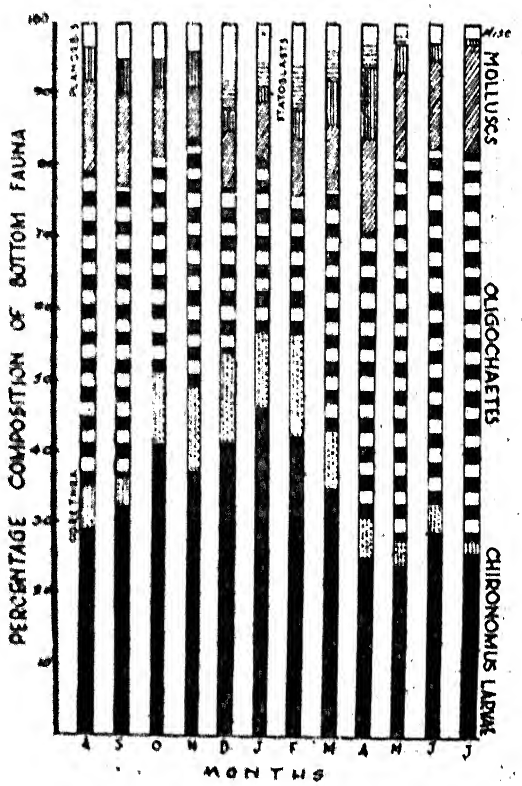
In both the water bodies under investigation it has been seen that oligochaetes featured in the main. They averaged high above 77·3 per cent in LaMartiniere in May but constituted upto 54·0 per cent in July in Kathauta. Their lowest population was recorded in the former during the month of February when it constituted about 32·7 per cent while in the later it was only 20·0 per cent. In LaMartiniere leeches shared between 3·4 per cent in April and 0·4 per cent in September, but were significantly rare in number in Kathauta.

Chironomus larvae revealed their maximum percentage to about 52·4 per cent in November but it was nearly 46·5 per cent during January in the Kathauta. They appeared in lowest numbers in LaMartiniere in April and shared only 3·0 per cent while no such wide range of fluctuations was noted in Kathuta in which the minimum percentage was 24·0 per cent in May. *Corethra* larvae which were seen in smaller numbers in LaMartiniere varied from 14·0 per cent to 2 per cent in Kathauta during the months of February and July respectively. Other insect larvae were represented in comparatively very small numbers and constituted hardly 5·6 per cent during December, and the lowest 0·8 per cent in the month of September in the LaMartiniere. Similarly in Kathauta their highest percentage was 6·5 per cent in December and the lowest being 1·0 per cent during May.

Among crustacea ostracods constituted between 6·9 per cent and 1·5 per cent during the months December and August respectively in the LaMartiniere. But they shared casually and significantly low percentage in Kathauta which did not exceed above 1·5 per cent. Cladocera were represented in 4·5 per cent in May and 0 8 per cent in February in the LaMartiniere but were very much scanty in the other. In LaMartiniere some shrimps were counted separately and their percentage varied between 6·6 and 0·7 per cent during the months June and February respectively.

In molluscs, *Planorbis* which appeared for a limited period constituted high upto 24·9 per cent during the month of February but declined to 3·2 per cent during

May in LaMartiniere. But in Kathauta *Planorbis* was observed throughout the year, although its population was appreciably low as compared to the former and constituted only 10·0 per cent in April to the lowest in July when percentage was only one per cent. Other gastropods appeared in 12·3 per cent, during August and 2·5 per cent in April, in LaMartinere while it fluctuated between 9·0 per cent in July to 3·0 per cent during November in Kathauta. Tebo (1955) listed about 36·0 per cent gastropods in Lizard Lake, Iowa. Bivalves were collected in comparatively in less number both from the LaMartiniere and Kathauta. Its percentage was never above 5·5 per cent but varied low to 1·2 per cent in the month of September in LaMartiniere while in Kathauta they made up about 7·0 per cent in August and 3 per cent during the months December and February.



Percentage composition of bottom fauna of Kathauta Lake.

Statoblasts constituted between 21·1 to 13·1 per cent during the months February and March in LaMartiniere. But shared only 6·0 per cent in February and 1·5 per cent during May in the Kathauta.

THE CORRELATION BETWEEN THE BOTTOM FAUNA AND THE FISH FOOD

The regular analysis of the gut content of the fishes revealed that their food consisted chiefly of some algae, insect larvae particularly *Chironomus* and nymphs of dragonfly and mayfly, bryozoan colony and their statoblasts, ologochaetes, shrimps,

molluscs, fish scales and their fins along with fragments of the decomposed as well as fresh aquatic plants and some sand or mud. On comparing these items with the bottom fauna catches it is established that the fishes under discussion find in the bottom zone conditions particularly favourable in these water bodies as they maintain good supply of insect larvae, oligochaetes, molluscs and crustacean.

Adamastone and Harkness (1923) while working on the bottom organisms of lake Nipigon found that the common white fish *Coregonus* feeds exclusivelly upon the bottom forms. Clemens *et al* (1923) have recorded that the food of sturgeons, northern suckers, common suckers, round and white fishes constitued chiefly of the bottom fauna. Similar observations have been also made by Adamstone (1924) for the larger specimens of perches of lake Nipigon. Rawson (1930) found ephemerid larvae to be an important item in the food of certain fishes in lake Simcoe. Hart (1931) has also reported that over ninty percent of large white fishes of Shakespeare Island lake consisted of *Chironomus*, *Corethra*, amphipods, cladocera and molluscs. Allen (1942) has further laid emphasis on the bottom fauna and has aptly compared it as the source of available food supply for fishes. No doubt, Das and Moitra (1955) have attempted to correlate the type of food taken to the mode of feeding of the fishes and have also sorted out certain bottom feeding fishes, but to my knowledge no year round data, on the available fish-food and its correlation to the food consumed by the fishes in nature has been published for Indian freshwater bodies.

On comparing the gut contents of these fishes with the bottom fauna catches, a remarkable correlation has been noticed for the first time for these fishes. The bottom fauna coupled with aquatic plants provide a rich source of the food supply for the fishes. The nature of the bottom zone appears to effect the available fish-food as the zone provides the anchorage, food, shelter and breeding place to the benthic organisms and bed for hydrophytes. The seasonal fluctuation in the components of bottom fauna decidedly effect the food of the fishes in that water body. The insect transformation and emergence has been also seen to influence the quality of the food taken by the fishes. Moreover, the benthic organisms are either at times adopted more or less to pelagic mode of life or have been noticed in plankton collections in some of their life-cycle stages, and as aptly put by Wesenberg-lund (1926) the home of fresh water plankton is to be found in the bottom of the lakes, there appears a close relationship between the benthic fauna and the standing plankton crop. Similar interesting correlations have been also recorded by Deevey (1941) and Rawson (1942). And thus, the bottom fauna also plays an important role in the food cycles of the fishes which feed on plankton. It is further concluded that the available food supply for the fishes belongs to the three main categories depending much on the habits, wheather the fish is a bottom feeder, column feeder or surface feeder. The knowledge of the food taken and the available food supply for the culturable fishes is very essential for selecting the right species of fish, so that it may be able to use maximum food preferences in a particular stretch of water, in all fish culture projects.

SUMMARY

The study of the bottom fauna which forms an important phase of the investigations on the available food supply for the fishes has revealed a rich and varied assemblage of different organisms present in north-Indian freshwater lakes. Oligochaetes, *Chironomus* larvae, insect larvae and molluscs formed the main bulk of the bottom catches.

The stomach contents (food-consumed in nature) of the fishes, which consisted chiefly *Chironomus* larvae, oligochaetes, molluscs, insects, small pieces of aquatic

weeds, fish scales along with some other burrowers, clingers, crawlers and hiders among the bottom materials showed marked qualitative and quantitative variations, with the succession of season, and the former showed a good correlation with the bottom catches.

The results obtained indicate clearly that the bottom fauna forms a very good source of the food supply for the fishes discussed in the present studies as demonstrated clearly by the examination of their gut contents.

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